

RAIL GRINDING MACHINE STUDY

Prepared for

Transportation Development Centre
Transport Canada

by

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Reid Crowther & Partners Ltd.

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17. Abstract The rail grinding machine study is an investigation of the development of rail grinding equipment suitable for the Canadian railroad and transit properties. The study addresses the causes and problems associated with rail defect, rail wear and corrugation and how the railroad and transit properties are currently responding to the rail grinding needs. A state-of-the-art of rail grinding technology; addressing heavy and light grinding machines and associated costs of purchase and leasing; was investigated. An alternative rail grinding program based on preventative grinding needs using a proven light rail grinder and performance requirements of the Canadian railroad and transit properties was prepared. Machine components and railhead measuring equipment including 'broad brush' cost estimates are also addressed in the study report.		16. TDC Project Officer Wayne Rowan	
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17. Résumé Cette étude fait le point sur l'état d'avancement des travaux de développement de matériels de meulage des rails, adaptés aux besoins des sociétés ferroviaires et entreprises de transports en commun canadiennes. Elle traite des problèmes à l'origine des défauts et avaries des rails comme l'usure ondulatoire et aborde les techniques et méthodes de meulage correctif et préventif actuellement mises en oeuvre par les sociétés intéressées. Elle fait un tour d'horizon de la technologie du meulage des rails: machines de meulage poussé et léger, coût d'acquisition et de location, etc. L'étude propose un nouveau programme de meulage axé sur la prévention, mettant en oeuvre une machine à meuler légère, éprouvée et répondant aux exigences des sociétés canadiennes ferroviaires et de transports en commun. Le rapport s'intéresse également aux divers organes des machines en question et aux instruments profilométriques utilisés dans le domaine; elle présente également des devis estimatifs à caractère très approximatif.		
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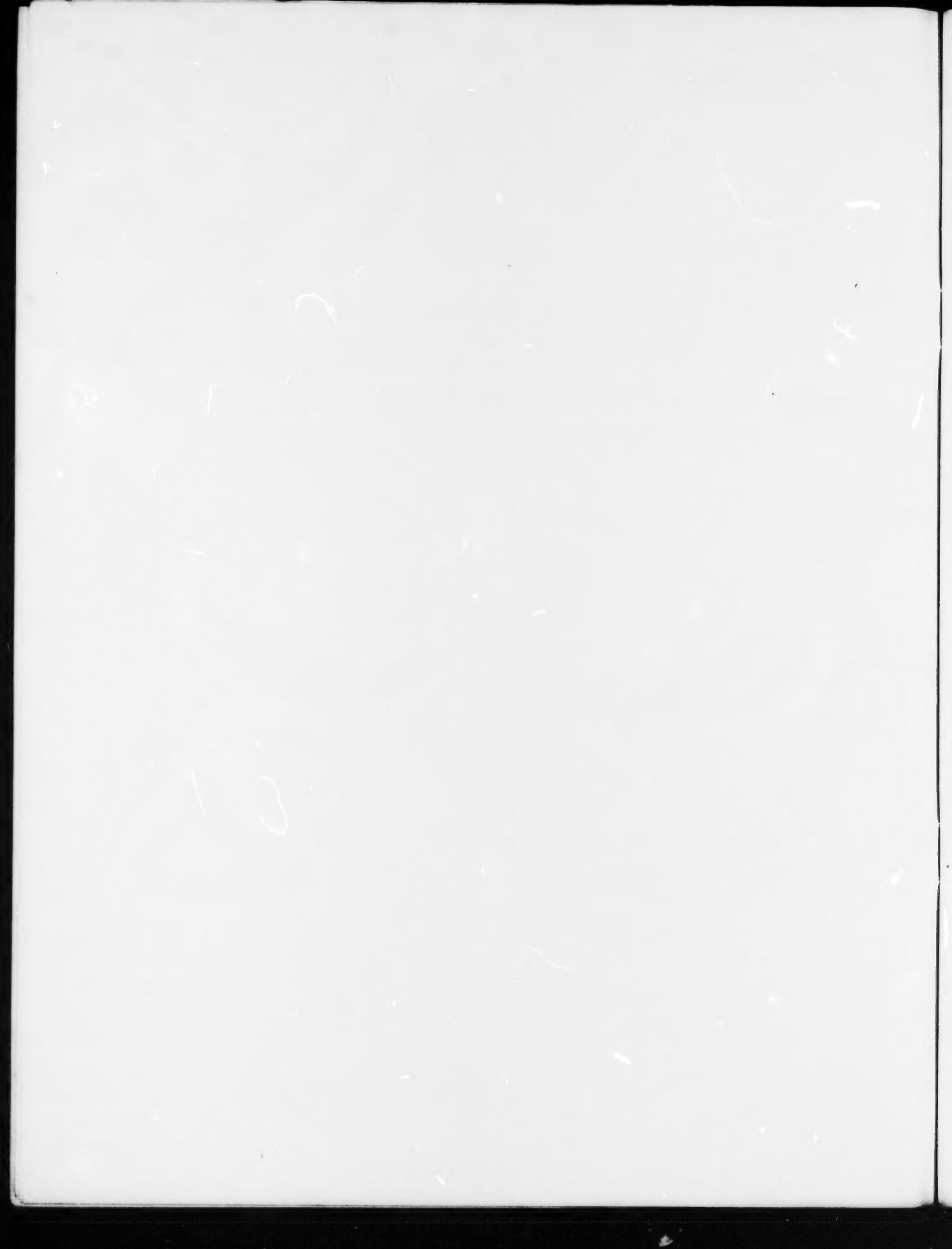
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EXECUTIVE SUMMARY

The rail grinding machine study was initiated to investigate the existing and future rail grinding requirements of railroad and transit properties and to identify the rail grinding machine concept that would better serve the needs of the industry.

Since the early 1970's, rail grinding practices have been mainly based on corrective grinding. In this study, corrective grinding is defined as grinding required to remove corrugations, remove impact fatigue defects and re-profile the rail head. Medium to heavy rail grinding machines are required to perform this work. Typically, these machines utilize a rotary grinding wheel mechanism comprising of 40 to 120 stones per unit. The technology of these machines has been well proven in operation. Ongoing research and development is progressing on the abrasives and bonding resins to improve the wear of grinding stones. Instrumentation and control are advancing rapidly to meet the evolving rail grinding requirements and 'on-board' control of grinding stone positions. Several manufacturers are currently testing rail head imaging systems to better define the grinding requirements and performance of the machines.

Most railroad and transit properties have now expressed interest in preventative grinding. In this study, preventative grinding is defined as frequent grinding required to reduce the propagation rate of corrugations. On railroads, preventative grinding is intended to prolong the life of rails and therefore reduce the cost of rail replacement. On transit properties, it has the added advantage of reducing air-borne noise emitted from the wheel/rail interface. Small rail grinding machines are adequate to perform this work.

In North America, three types of small rail grinding machines at various stages of development are in use. The linear grinding machine or block grinder has the ability to 'polish' the rail head and therefore provide a smoother rail interface with the wheel. The ability of this machine to reduce noise level has been accepted and therefore in certain transit

systems, it has definite applications. The linear grinder is not capable of rail profile grinding and is considered inefficient for removing rail corrugations and defects. The belt grinding is still in an early development stage. Although the concept is viable, there remains considerable work to improve the wear of the belt and make the machine more efficient in the areas of metal removal, tracking in tight curves and its ability to re-profile the rail. The small rotary grinder appears to best meet the preventative grinding requirements of railroad and transit properties.

The small rotary grinder is a scaled-down version of the heavy rotary grinders and typically has less instrumentation and sophistication. The low capital cost of this machine makes it more affordable for purchase by railroad and transit properties. On railroad properties, corrective grinding will continue to be a requirement on the basis of multiple trips per year. The small rotary grinder is especially useful for more frequent grinding on curves which experience heavy loading and rail wear and on switches, crossings and other special trackwork structures. On transit properties, the small rotary grinder meets most of the transit constraints on grades, curves and dynamic envelopes and is used mainly for removing corrugations and reprofiling rail.

The concept of a small rotary grinder is a modular, self-propelled unit capable of rail profile grinding featuring short wheel base, small diameter grinding stone mounting capabilities and small diameter wheels. The basic module should efficiently couple to other identical units to increase the work output of the machine. It should have the capability of high travel speed between sidings and worksites and have a high working speed. Its dimensions should fit within the dynamic envelope of trackwork and guideway structures existing in North America. The machine should have the ability to grind rails in either forward or reverse direction and be highway transportable.

SOMMAIRE

Cette étude a été lancée dans le but de faire le point sur les besoins actuels et futurs des sociétés ferroviaires et entreprises de transports en commun en matière de meulage des rails, et de déterminer les caractéristiques de la machine à meuler qui répondrait le mieux aux besoins définis.

Depuis le début des années 70, les pratiques en matière de meulage des rails ont essentiellement pour but un traitement correctif, c'est-à-dire l'élimination de l'usure ondulatoire et des défauts de fatigue sous impact, et le reprofilage du champignon des rails. Ce type de traitement exige des machines de meulage intermédiaire ou lourd généralement du type à meules rotatives au nombre de 40 à 120 par appareil. La technologie de ces machines est bien éprouvée et, du côté des abrasifs et liants utilisés, la recherche et développement visant à améliorer les caractéristiques d'usure des meules va de l'avant. Plusieurs constructeurs de matériels de meulage font actuellement l'essai de systèmes opto-électroniques de suivi de l'état des rails, visant à mieux définir les paramètres de meulage et les exigences de performance des matériels utilisés.

La plupart des sociétés ferroviaires et entreprises de transports en commun s'intéressent depuis peu au meulage préventif, c'est-à-dire les traitements légers à fréquence élevée visant à réduire le taux de propagation de l'usure ondulatoire. Les sociétés ferroviaires misent sur cette technique pour prolonger la vie utile des rails et, partant, réduire le fardeau que représente le renouvellement de ces derniers. Les entreprises de transports en commun voient dans cette technique l'avantage additionnel d'une réduction des nuisances sonores liées au frottement roue-rail, sans compter que des matériels légers suffisent à la tâche considérée.

En Amérique du Nord, trois types de matériels légers plus ou moins perfectionnés sont couramment utilisés. Les machines à patins meuleurs permettent de "polir" le champignon du rail et adoucir par le fait même le roulement des roues sur les rails. L'aptitude de cette machine à réduire les nuisances sonores est reconnue et en fait un matériel que certaines entreprises de transports en commun trouvent nettement avantageux. Par contre, elle ne peut servir au reprofilage des rails ni à l'élimination efficace de l'usure ondulatoire et autres avaries des rails. La machine à meuler à ruban est encore aux premiers stades de son développement. Bien que le concept soit valable, il reste beaucoup à faire pour en améliorer les performances sur le plan de l'épaisseur de matière enlevée, de l'inscription dans les courbes prononcées et du reprofilage des rails. Les petites machines à meules rotatives semblent les mieux adaptées aux besoins de meulage préventif exprimés par les sociétés ferroviaires et de transports en commun.

Il s'agit dans ce cas d'une version de format réduit des trains meuleurs lourds, qui est forcément moins perfectionnée et pourvue de moins d'instruments de contrôle et de mesure. Par contre, son faible coût d'achat en fait un matériel plus accessible aux entreprises de transports en commun et sociétés ferroviaires. Ces dernières auront toujours besoin de pratiquer le meulage correctif à plusieurs reprises dans une année. Cette petite machine à meules rotatives est particulièrement bien adaptée aux meulages fréquents qu'exigent les voies en courbe lourdement

circulées ainsi que les aiguillages, traverses et autres appareils de voie particuliers. Elle s'accommode de la plupart des contraintes spatiales imposées par les réseaux de transports en commun - rampes, courbes et gabarit d'encombrement cinématique - et elle sert essentiellement à l'élimination de l'usure ondulatoire et au reprofilage du champignon des rails.

La petite machine à meules rotatives idéale est un appareil modulaire automobile capable d'exécuter le reprofilage des rails et caractérisée par un faible empattement, la possibilité de l'équiper de meules de faible diamètre et aussi de roues de faible diamètre. Le module de base doit pouvoir être couplé efficacement à d'autres unités identiques pour accroître le rendement de la machine. Cette machine idéale devrait pouvoir se déplacer à haute vitesse entre chantiers et afficher une vitesse de travail élevée. Ses dimensions devraient s'inscrire dans le gabarit limite des obstacles et structures de guidage caractérisant les réseaux nord-américains. Cette machine devrait pouvoir exécuter le meulage des rails aussi bien en marche arrière qu'en marche avant et, enfin, elle devrait pouvoir être transportée par véhicule routier.

RAIL GRINDING MACHINE STUDY

TABLE OF CONTENTS

	<u>Page</u>
Report Documentation Form	(i)
Formule Documentaire Du Rapport	(iii)
Acknowledgement	(v)
Executive Summary	(vi)
Sommaire	(viii)
1.0 INTRODUCTION	1-1
1.1 Scope of Work	1-1
1.2 Study Objectives	1-1
1.3 Report Organization	1-2
2.0 PROBLEM IDENTIFICATION	2-1
2.1 Rail Defects	2-1
2.2 Rail Wear	2-3
2.3 Corrugation	2-5
2.3.1 Corrugation on Heavy Haul Railroads	2-5
2.3.2 Corrugation on Transit Track	2-6
2.4 Observations of Maintenance of Way	2-7
3.0 CURRENT RAIL GRINDING PROGRAMS	3-1
3.1 Major Railroads	3-2
3.1.1 Canadian National Railway	3-2
3.1.2 Canadian Pacific Railway	3-3
3.2 Other Railroads	3-4
3.2.1 British Columbia Rail	3-4
3.2.2 Quebec North Shore and Labrador Railway	3-5
3.2.3 Cartier Railway	3-6
3.2.4 Ontario Northland Railway	3-7
3.2.5 Algoma Central	3-8

RAIL GRINDING MACHINE STUDY

TABLE OF CONTENTS

(cont'd)

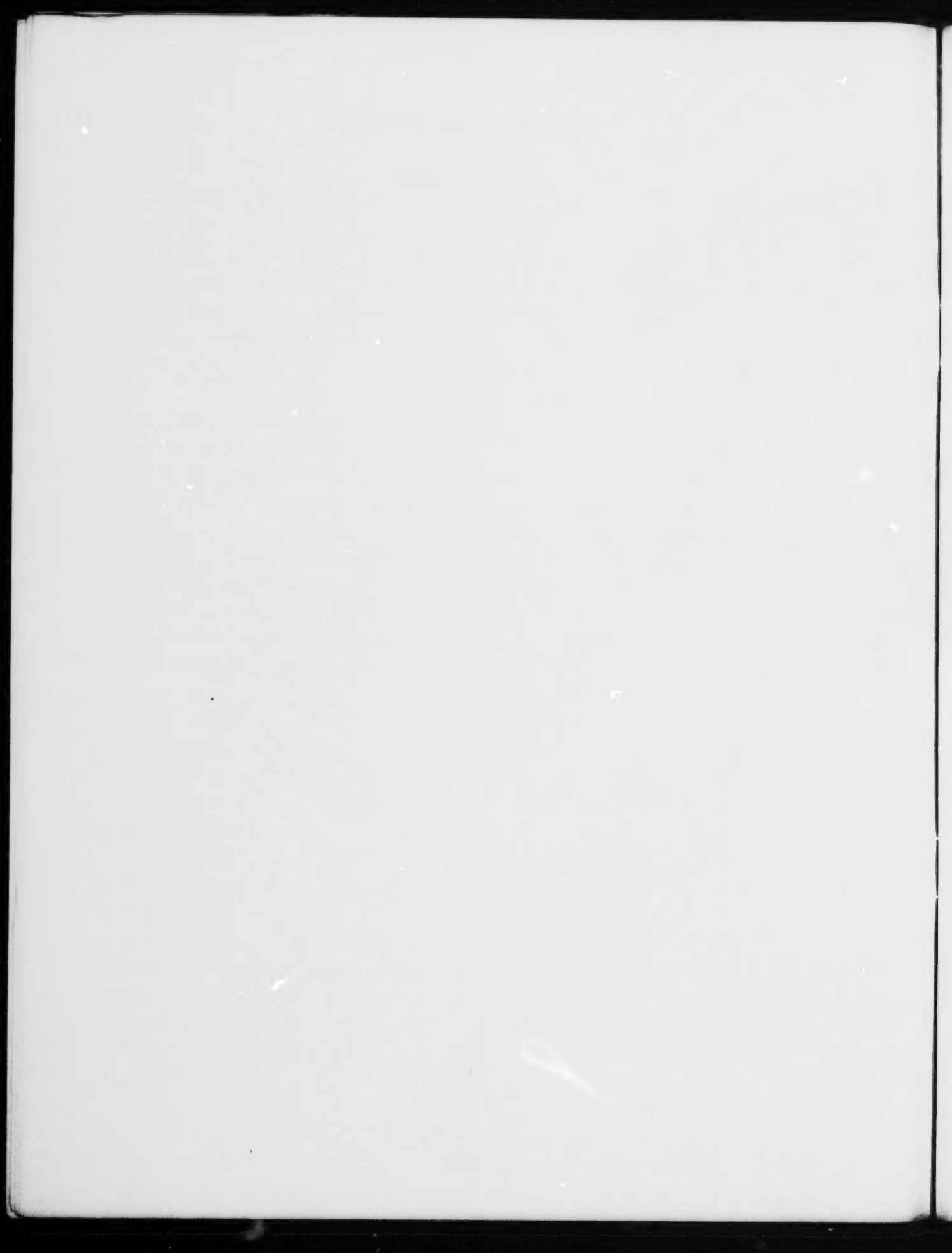
	<u>Page</u>
3.3 Transit Properties	3-8
3.3.1 British Columbia Transit	3-8
3.3.2 Calgary Transit	3-10
3.3.3 Toronto Transit Commission	3-11
4.0 STATE OF THE ART OF RAIL GRINDING TECHNOLOGY	4-1
4.1 Heavy Grinding Machines	4-1
4.2 Light Rail Grinders	4-3
4.3 Costs	4-5
5.0 ALTERNATIVE RAIL GRINDING MACHINE	5-1
5.1 Preventative Grinding	5-1
5.2 Technologies	5-2
5.3 Rotary Stone Rail Grinding Machine	5-3
5.4 Performance Requirements	5-3
5.4.1 General	5-3
5.4.2 Dimensions and Weight	5-4
5.4.3 Machine Components	5-4
5.4.3.1 Axles and Wheels	5-4
5.4.3.2 Brakes	5-5
5.4.3.3 Propulsion	5-5
5.4.3.4 Power Supply	5-5
5.4.3.5 Electric	5-6
5.4.3.6 Hydraulic	5-6
5.4.3.7 Grinding Modules	5-6
5.4.3.8 Grinding Wheels	5-7
5.4.3.9 Metal Removal	5-8
5.4.3.10 Dust/Dirt Control	5-8
5.4.3.11 Fire Control	5-8

RAIL GRINDING MACHINE STUDY

TABLE OF CONTENTS

(cont'd)

	<u>Page</u>
5.4.3.12 Cab and Controls	5-9
5.4.3.13 Safety Equipment	5-9
5.4.3.14 Couplers	5-10
5.4.3.15 Rail Head Measuring Equipment	5-10
5.4.3.16 Optional Equipment	5-10
5.4.3.17 Maintainability	5-10
5.4.3.18 Replaceability	5-11
5.5 Equipment and Costs	5-11
5.6 Rail Head Imaging and Grinding Wheel Control Technology . .	5-12
5.6.1 Rail Head Profile Monitoring System	5-12
5.6.2 Grinding Wheel Control System	5-13
6.0 REFERENCES	6-1



LIST OF APPENDICES

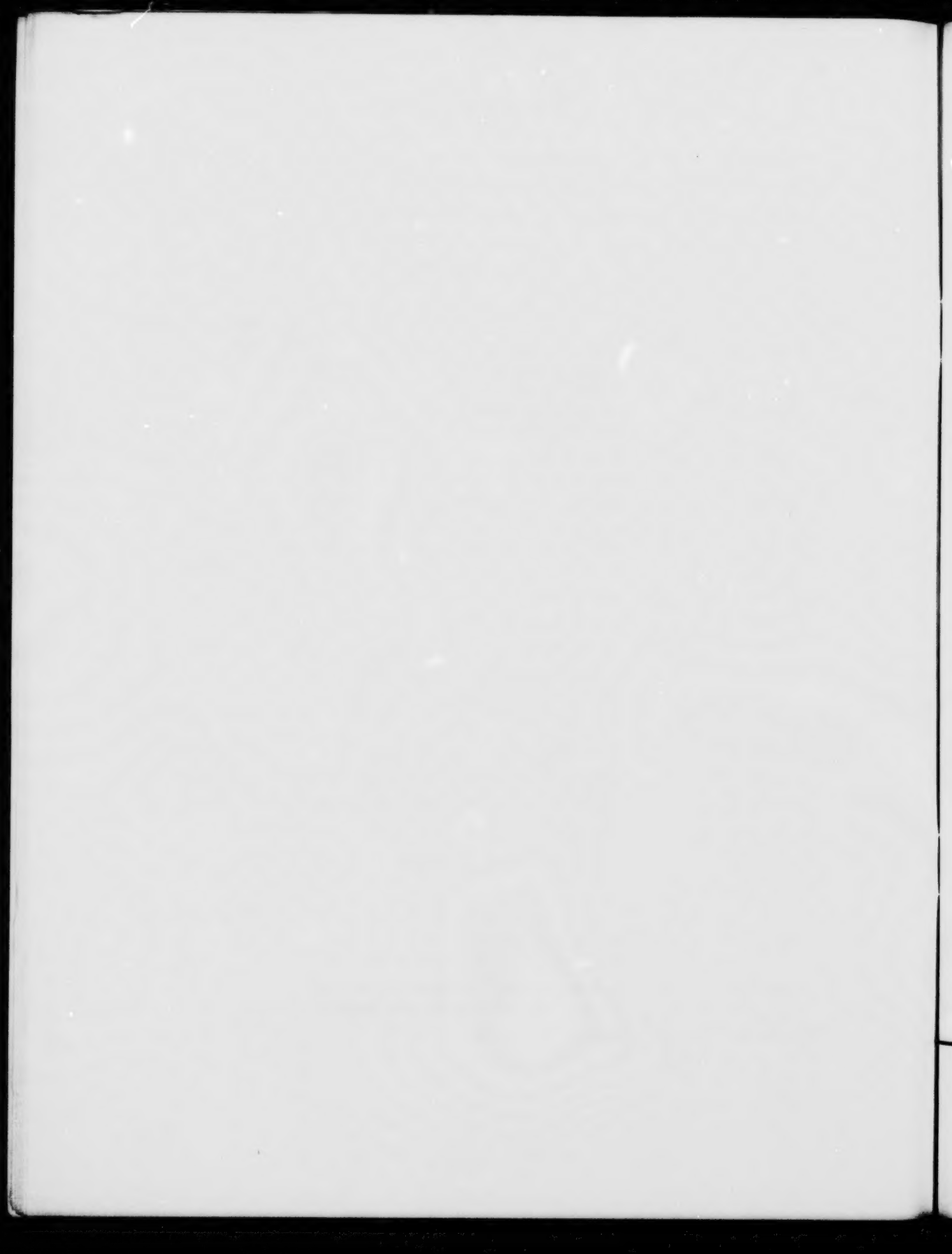
APPENDIX A	-	Portec Gauge
APPENDIX B	-	RGM Rail Grinding Monitor
APPENDIX C	-	Plasser & Theurer Rail Planer

LIST OF FIGURES

		<u>Following Page</u>
FIGURE 1	-	Relative Frequency of Contact (pummelling) of Rails in 8° Curve Without Preventative Grinding 2-2
FIGURE 2	-	Theoretical Contact Points for 136 RE Rail Section at 1:40 Cant 2-3
FIGURE 3	-	Dynamic Measurement of Rail Vertical Profile Bolted Track - Speed = 30 MPH (48 km/h) 2-3
FIGURE 4	-	Dynamic Measurement of Rail Vertical Profile Grade Crossing - Speed = 64 MPH (103 km/h) 2-3
FIGURE 5	-	Section of Rail Showing Severe Gauge Face Wear 2-4
FIGURE 6	-	Speno RSM-1 3-2
FIGURE 7	-	Fairmont RG-16 3-2
FIGURE 8	-	Loram RGM-1 3-4
FIGURE 9	-	Dynamic Envelopes for Various Transit and Freight Trains 3-8
FIGURE 10	-	Gallant Belt Grinder 3-8
FIGURE 11	-	Block Grinder 3-8
FIGURE 12	-	Heavy Rail Grinder Comparison Chart 4-1
FIGURE 13	-	Light Rail Grinder Comparison Chart 4-1

LIST OF TABLES

		<u>Following Page</u>
TABLE 1	-	Summary of Existing and Projected Rail Grinding Programs 3-1
TABLE 2	-	Summary of Rail Grinding Criteria, Priorities and Operational Requirements 3-1
TABLE 3	-	Summary of Costs 4-5



1.0 INTRODUCTION

1.1 Scope of Work

The rail grinding machine study investigates the possibility of the development of rail grinding equipment suitable for the Canadian light and heavy rail market. Existing and projected rail grinding requirements of both railroad and transit properties would be collected and evaluated and performance criteria defined. A machine which would best serve the needs of the industry and the cost of development of the machine would be investigated and presented.

1.2 Study Objectives

- To investigate the rail problems in heavy haul and transit trackwork systems which lead to the requirement of rail grinding.
- Review of existing and projected rail grinding programs of Canadian railroad and transit properties.
- Assessment of rail grinding criteria, priorities and operational requirement of each property.
- Review of physical limitations, load constraints and operational requirements of each property.
- Review of the state of the art of rail grinding machine technology.
- Identification of performance criteria for the rail grinding services required.
- Preparation of an alternative rail grinding program.

- Development of a performance specification for a conceptual machine to meet the needs of the industry.
- Preparation of cost estimates of the base grinding machine and all major components.

1.3 Report Organization

The report is presented in four sections which deal with the following matters:

- Problem identification section summarizes a study of rail defects, rail wear and corrugations. Differences between transit and railroad trackwork are presented showing the causes of rail problems which are being partially addressed by frequent rail grinding.
- Current rail grinding program section deals with existing grinding programs for railroad and transit properties.
- State of the art of rail grinding technology section identifies and compares heavy rail grinders and light rail grinders.
- The alternative rail grinding program section discusses the technologies of preventative grinding and identifies the grinding machine suited to the current and future needs of railroad and transit properties.

2.0 PROBLEM IDENTIFICATION

In order to define the effectiveness of a rail grinding program, it was considered necessary to investigate the problems associated with the deterioration and early replacement of rails in both transit and railroad systems. As part of this project, we have made direct observations of these conditions on transit and railroad systems in British Columbia and Alberta.

Three problems causing the early deterioration of the running rail under normal operating conditions are usually associated with:

- rail defects;
- rail wear; and
- rail corrugation.

2.1 Rail Defects

With the advent of the 100-ton car and unit trains, rail defects which would not likely have caused undue concern in the past have suddenly become critical to the heavy haul railroad properties. High speed transit trackwork, although not subjected to heavy loading, has also been plagued with rail defects and associated problems. In our discussions with the railroad and transit authorities we find that rail defects are of major concern to them. This is especially true with the heavy haul properties, where subsurface defects could propagate to the surface quickly and without warning, causing rail breaks and risking derailments. Transit authorities are not only concerned with the possibility of derailments but also with the ride conditions and noise level aggravated by rail defects.

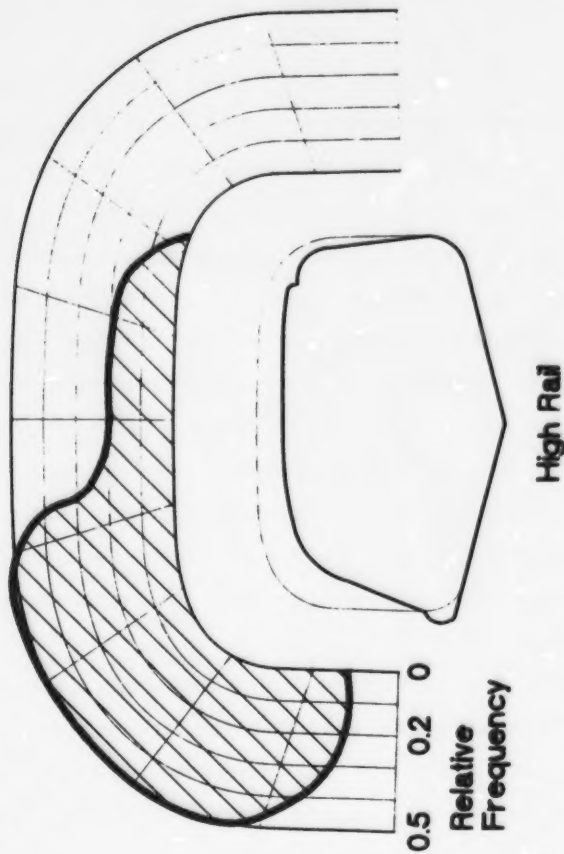
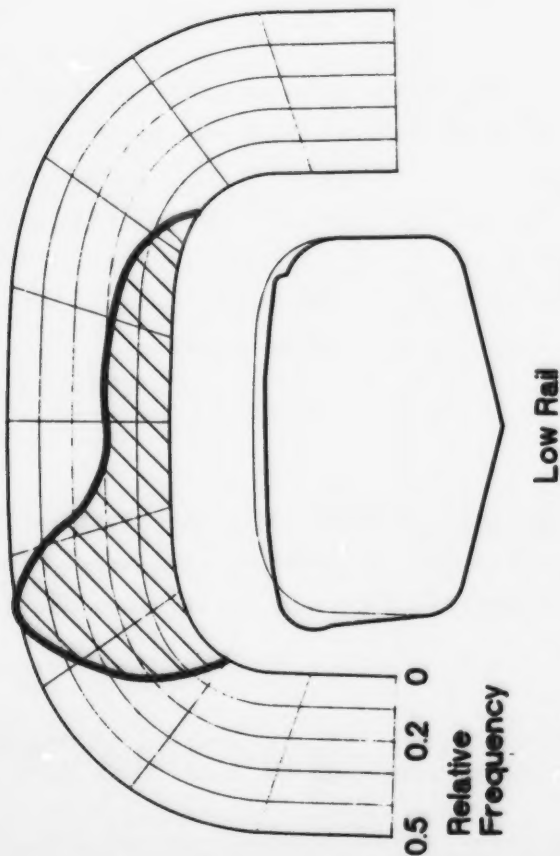
Unclean rail steel, inclusions and minor surface imperfections which originate in the rail mills are some of the causes of defect initiation. Until recently, standard carbon steel rails have been adequate in terms of metallurgy, cleanliness, strength and resistance to abrasion. With

increasing train loads and excessive rail wear, steel specifications have been changed in an attempt to reduce rail defects and improve the quality of steel to meet the new operating conditions. Rail manufacturers are aware of the problems and during the past few years have actively upgraded their mills to conform to the new requirements. The new strand cast steel is cleaner than ingot steel, metallurgy is more easily controlled, and quality assurance and quality control programs have been modified to meet the buyers requirements.

Tangent track, if maintained in good surface, gauge and alignment, is relatively trouble free even at fairly high operating speeds and with heavy axle loadings. On curves the gauge corner of the high rail is subjected to high impact loadings. The severity depends on the compatibility of the worn wheel with the profile of the rail head, curvature, super elevation, gauge, track structure condition, truck steering characteristics and speed. Poor track conditions on curves are subjected to slow orders. When trains operate below the design operating speed, the load shifts to the low rail where these dynamic forces can create plastic deformation of the field side of the rail head. Even when trains are operating on slow speeds there are high lateral forces acting on the high rail. Subsurface defects, such as inclusions, minor gauge corner cracks, spalling or shelling conditions are continuously undergoing high impact loads. When this type of impact fatigue loadings are occurring, defects can grow at a high rate resulting in the early replacement of rails (1, 2). Figure 1 illustrates the loading conditions both on the low rail and on the high rail on a curve not subjected to preventative grinding.

Transit and railroad authorities are also concerned with the rail/wheel interface. Wheel profiles that are not matched to rail profiles can cause defect propagation in rails. Research groups have been studying interface problems and their impacts on rail and wheel defects.

An example of the importance of wheel/rail interface was noted in late 1987 on BC Rail's heavy haul area just north of Prince George where CN Rail had been hauling unit coal trains. BC Rail, in conjunction with CIGGT, the



Relative frequency of contact (pummeling) of rails in 8' curve without preventative grinding.

RAIL GRINDING MACHINE STUDY

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Figure 1

NRC and Loram Maintenance of Way, Inc., have been conducting rail grinding tests in this area since September of 1986. In November 1987, following 4 MGT on the 6° and 8° curves in the test area, the test team returned to conduct the third round of grinding tests. Compared to the condition of the rail at the end of the previous test there were excessive shellings evident on the high rail on these curves. This was unexpected and unusual for this low volume of use. The condition was caused by the CN wheels which were worn to the CN 4-inch crown radius profile, which were now running on B.C. Rail newly profiled 8-inch and higher crown radius. The loading pattern showed two contact points on the rail head. On curves the gauge corner of the high rail was taking the worst loading and high contact stresses evidenced by the rapid growth of the noted impact fatigue defects. Figure 2 demonstrates a standard AAR wide flange wheel on various crown radii.

With identification of the defect problems relating to heavy haul track and the subsequent response from the rail manufacturers, the industry has come a long way in coping with these defect problems. Harder and better quality rails have been used recently creating another problem. Wheel wear problems become more prominent as the hardness of the wheel, typically 363 Bhn, is lower than the head hardened and premium rails being specified for heavy haul areas, which are now up to 405 Bhn.

Engine burns, crushed rail head, battered rail ends on bolted connections and battered welds are also defects which can be quickly worsened by heavy axle loads. Dynamic vertical movement of rail in poorly maintained tracks has been known to exceed the tolerance on bolted joint connections and especially on crossings which are difficult to maintain. Figures 3 and 4 show typical vertical deflections of bolted tracks and poorly maintained grade crossings obtained from a railroad property.

2.2 Rail Wear

The use of premium and head hardened rails in curves subject to heavy axle loadings have been significant in reducing rail wear. Deep head hardening of the rail offers increased resistance to abrasion and is being used more

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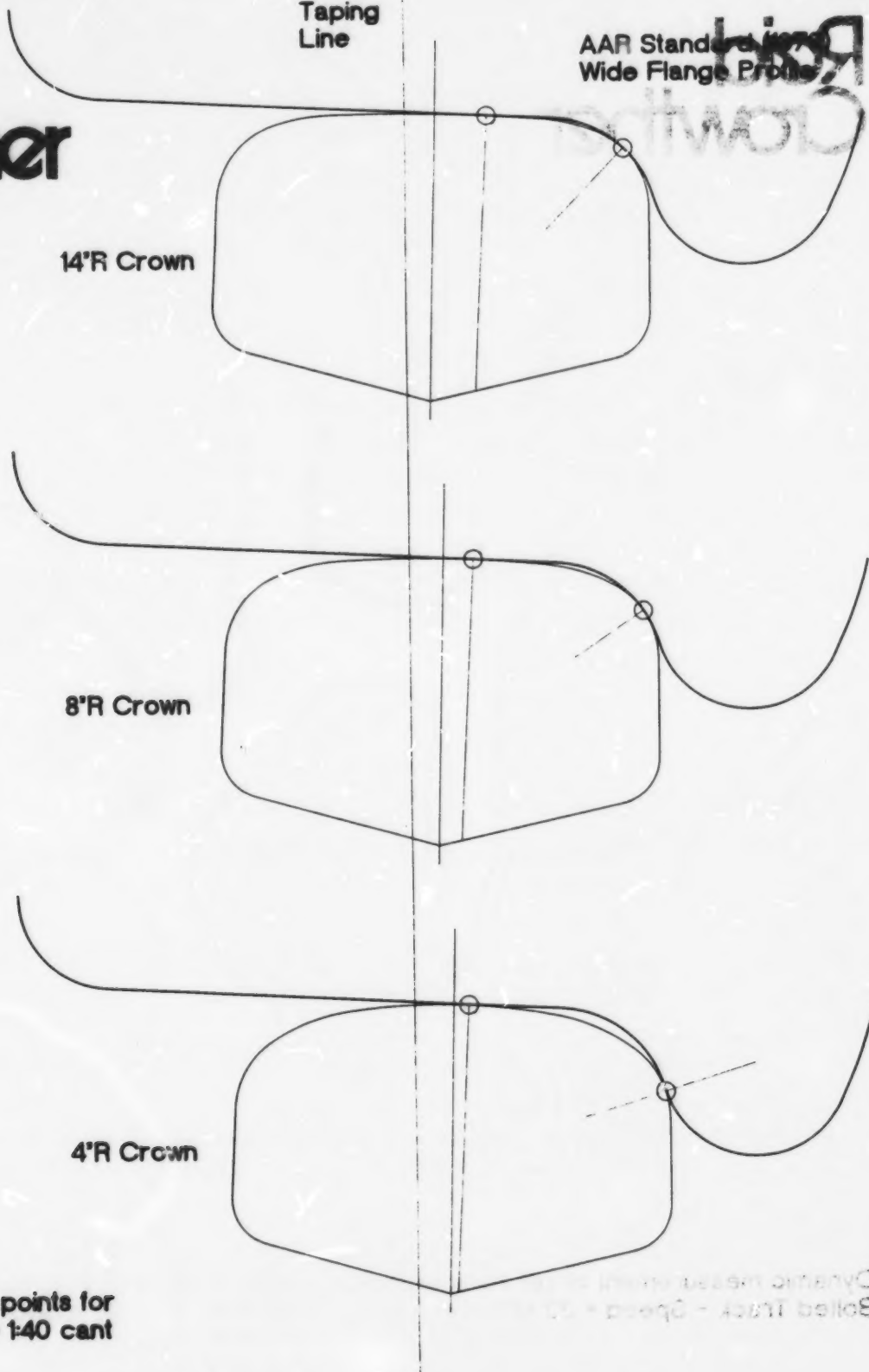
Taping
Line

AAR Standard 1979
Wide Flange Profile

14"R Crown

8"R Crown

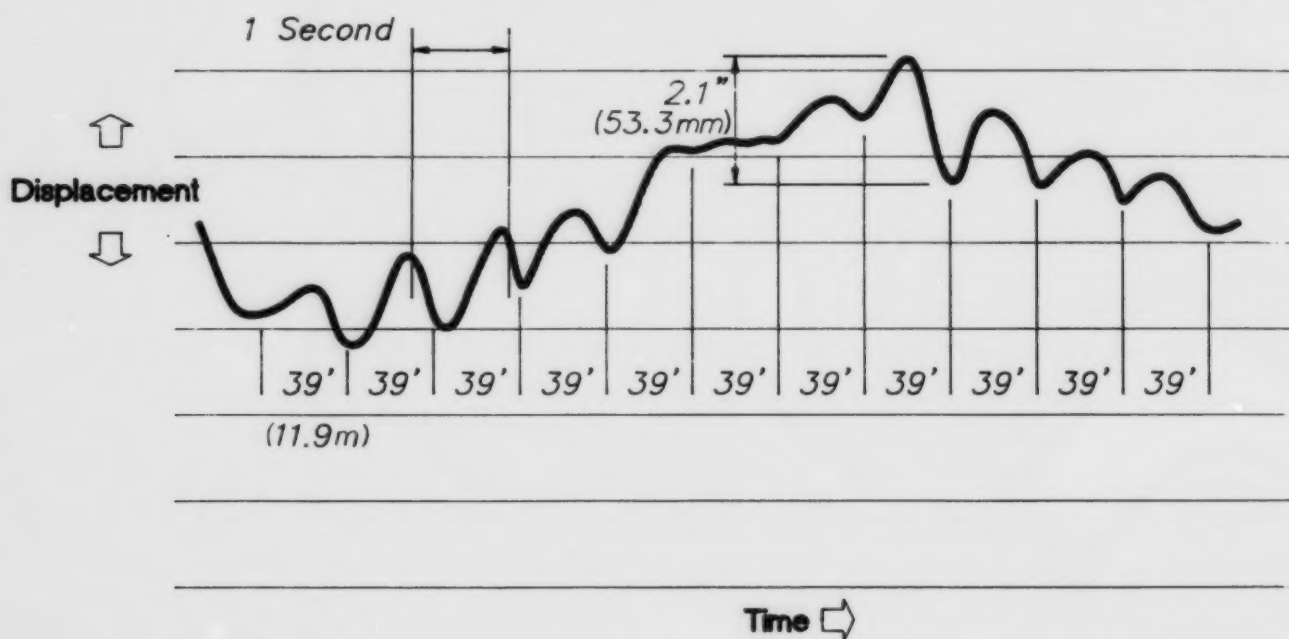
4"R Crown



Theoretical contact points for
136 RE rail section • 140 cant

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UP-P-214

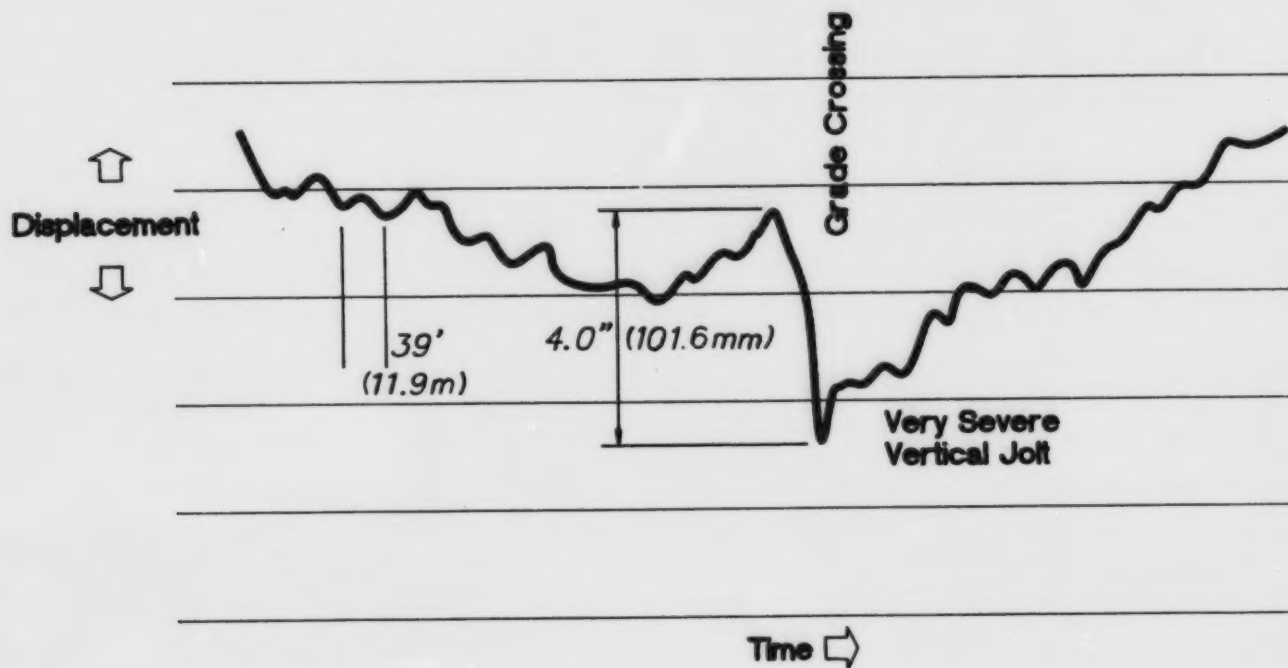
Figure
2



Dynamic measurement of rail vertical profile
Bolted Track - Speed - 30 MPH (48 km/h)

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Figure
3



Dynamic measurement of rail vertical profile
Grade Crossing - Speed - 64 MPH (103km/h)

and more in the industry. The primary zone of rapid wear is on the gauge corner and gauge face of the high rail in curves of over 4°.

This wear is caused by wheel abrasion where the leading wheel set exerts vertical and lateral forces on the high rail, combining to wear away materials from the gauge corner and face of the rail. Figure 5 shows extreme gauge face wear usually encountered on heavy haul railroads. The low rail in a tight curve also experiences wear, not from abrasion, but from plastic deformation and outward movement of the work-hardened surface of the loaded rail. A flattened head and resultant field side lip is typical of this form of wear. Figure 1 is a good example of the wear and flattening of the low rail on a curve.

Railroad properties have been concerned with the rail wear problems especially on curved tracks. Researchers have suggested self-steering trucks and modified truck designs as partial solutions to the curve wear experienced by the heavy haul properties.

The Cartier Railroad have experimented with modified truck designs and claim to have realized a 30% improvement in rail/wheel wear life by widening the side frame pedestals to give longitudinal springing, and using widened adaptors to provide greater relative lateral movement between axles and side frames (14).

The use of radial trucks is expected to greatly relieve rail wear problems, and reports have confirmed this. During the course of this study, we were able to observe only one type of radial trucks and have discovered that it did not self-steer at speeds below 60 km/h (40 mph). In view of the typical slow speeds in tight curves which are prone to gauge face wear this type of radial truck is ineffective.

High rail lubrication in curves has been effective in reducing gauge face wear and is now an accepted practice on most railroads. One problem associated with rail lubrication is the migrating of excess lubricant onto the rail head where existing defects are contaminated. The addition of

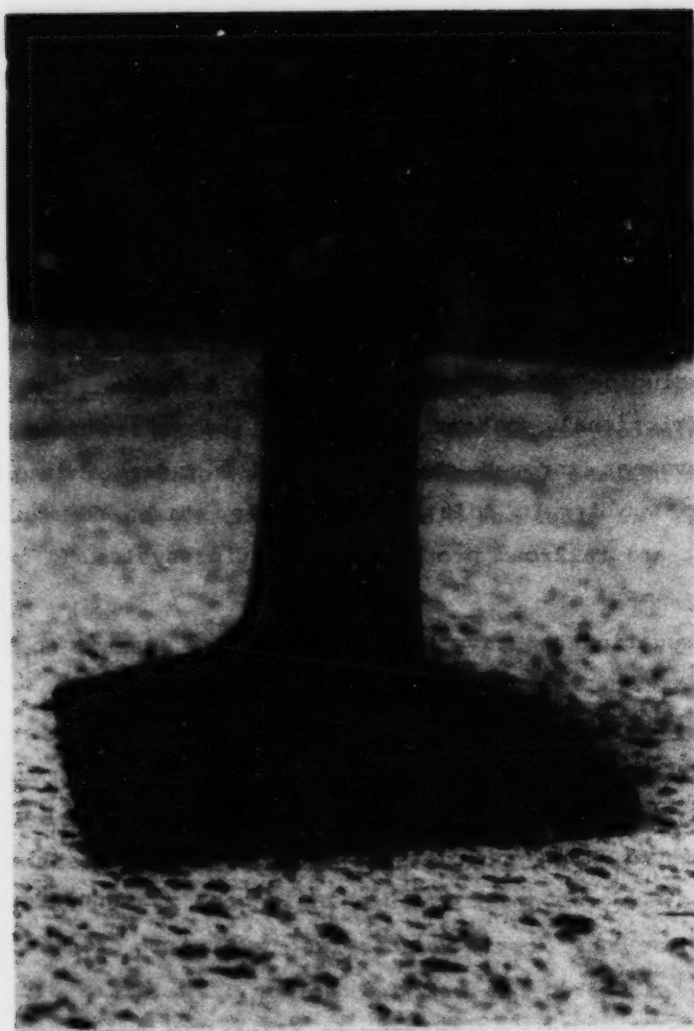


Figure 5: Section of Rail Showing Severe Gauge Face Wear

the rail head where existing defects are contaminated. The addition of lubricant to the defects (micro-cracks and spalls) delays the initiation of surface and contact fatigue cracks on one hand, but accelerates propagation of established defects on the other hand (2, Page 29).

2.3 Corrugation

Corrugation according to Webster is any series of parallel folds, ridges or furrows. In the railroad industry such descriptive formations occurring in rails are easily identifiable but very difficult to attribute causes to.

There are two current theories which explain the cause of corrugation, interacting with rail head defects and track conditions. They are contact resonance; which is defined as resonance vibration of the wheel and rail system, including axles, rails and ties; and the stick-slip theory which explains frictional contact instability between wheels and rails during vehicle movement through curves. A full understanding of the cause of corrugation would make solutions an easier task and would greatly improve the transit and railroad properties operating system.

2.3.1 Corrugation on Heavy Haul Railroads

Usually corrugations do not occur to any measurable extent on tangent track. Typical corrugations initially occur on the low rail in curves which are subject to high traffic tonnage and high speed. If low rail corrugations are not removed, then corrugations would appear on the high rail as well.

Corrugations on heavy haul routes show varying pattern, but it would seem that long wave corrugations of 2.1 m (7 ft) length with superimposed shorter waves down to 0.6 m (2 ft) to a typical maximum depth of .508 mm (.020 in), are fairly common (11). "Fast", in Pueblo, Colorado, have identified short wave corrugations in the 152-203 mm (6 in - 8 in) length with a range of 150-762 (6 in - 30 in) being common on many heavy haul railroads in the U.S.A. (5). Depth growth of 1 mm (.040 in) in a four-month period is common on standard carbon rail. Unclean rail steel and rail head defects such as mill scale, non-metallic inclusions (debris) and small surface cracks are some of the origin points of corrugations (7).

Track sub-structure conditions including ballast and cross ties are also critical to the development of, or resistance to corrugation. Most railroad properties have changed wooden ties on curves with concrete ties which have been reported to perform better. Rail fixation is improved with use of concrete ties, but if corrugations are present, the impact loads and contact stresses on the more rigid track structure are severe, leading to crushing of rail support pads and cracking of ties, as well as regrowth of corrugations (6).

2.3.2 Corrugation on Transit Track

Transit properties in Canada experience rail defect and corrugation problems similar to the heavy haul freight properties. Defects are propagated by the same mechanisms (contact fatigue, dynamic reaction), but little study or experimentation has been done to date in order to understand the scope of the problem. Suggestions are that tight gauge tolerances, wheel design and diameter, rail profile, design of axles, and track structure rigidity interacting with soft rails, mill scales, spalled and pitted rails are some of the problems being faced by transit properties.

The occurrence of short wave length corrugation (roaring rail) in tight curves appears to be unique to transit properties. These corrugations typical range in depth from 0.12 mm (.005 in) to 0.5 mm (.020 in). On the Vancouver SkyTrain System corrugations form at a 57 mm (2 1/4 in) peak

distance on small radii curves. British Railways record corrugations (8) of a 40-70 mm (1 1/2 in-2 3/4 in) wavelength in various curves on their system. Both properties have noted a martinitic layer on the top of corrugation peaks in some cases. Roaring rail nuisance noise is an additional problem faced by transit properties.

Experiments carried out on rail profile grinding appear to have corrected some of these problems and prevent their re-growth.

2.4 Observations of Maintenance of Way

When questioning the effectiveness of various grinding programs it was necessary to review the conditions and preparation of track prior to rail grinding. It is desirable to have a track surface of constant variation with little vertical deflection with a maximum of 25 mm accepted on railroads. It is also desirable to have repairs completed on battered rail ends, and to assure that engine burn and crushed rail defects are repaired or rail plugs installed prior to grinding. With the occurrence of wide dynamic gauge in curves with some reports of 38 mm plus being observed and the associated low rail corrugations, it would be desirable that maintenance of way crews could correct as many of these problems as possible in advance of the grinding train. It has been the experience of study investigators that this preparatory work can be improved.

3.0 CURRENT RAIL GRINDING PROGRAMS

In this study corrective grinding is defined as grinding required in order to remove corrugations, impact fatigue defects and to re-profile rail head. Preventative grinding is defined as maintenance grinding to prevent recurrence of corrugations and fatigue defect growth.

Rail grinding practices have been mainly corrective grinding for most railroad properties from the early 1970's until recently. The advent of the 100-ton car and unit trains running on existing track systems have accelerated corrugation growth, rail wear and rail defect growth which lead to an increase in the maintenance of way budgets (10). It was discovered that partially ground corrugations quickly re-established their growth patterns, and the railroad properties not having their own equipment found themselves in a "catchup" situation. Speno and Loram were responsive to their needs and have developed and manufactured more heavy grinding equipment to meet the requirements of more frequent grinding necessary to eliminate the rapid growth of corrugations. Research into corrugation, impact fatigue defects, improved rail steel and grinding equipment design was intensified and Maintenance of Way budgets were increased in order to meet the demand.

The current attitude of Railroad and Transit properties in Canada is that a program of preventative grinding, rail lubrication and use of alloy or head hardened rail will help to reduce grinding requirements and prolong the life of rails on their systems.

Table 1 is a summary of existing and projected rail grinding programs. Table 2 summarizes rail grinding criteria, priorities and operational requirements.

CNR	C P R	B.C. Rail	Quebec, N.S. + Labrador	Canter Railway	Ontario Northland	Algoma Central	B.C. Transit	Calgary Transit	Toronto Transit
LENGTH OF SYSTEM km	34,010	2846	636	416	825	518	11	28	109.82
REGULAR RAIL GRINDING PROGRAM	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
APPROXIMATE COST OF PROGRAM PER YEAR \$		\$700,000	\$348,000 Avg. over 3 years					Net established program start 1987	\$33,000/yr - Labour
RAIL GRINDING FUNCTION and FREQUENCY	Control corrug. & profile - 4 passes/yr in heavy haul areas	Profile 10 MGT Preventative 5-10 MGT	As required 782 pass miles (1258 km) in 1987	As required 2200 pass miles/yr 3540 km/yr	Control wear 2 trips/yr		Roaring rail/wear/ride continuous	Not yet defined	Quarterly. More on small radius curves
EXISTING RAIL GRINDING PROGRAM		Loram RCM-1 Owned	Loram 36 stone grinder Owned	Loram 24 stone grinder	Spene RMS-12 120 stone	None	4 belt grinder 12 stone block grinder	Fairmont RC-8 Owned	Block grinders Owned
APPROXIMATE COST \$		\$4.5 Million	Undisclosed	Undisclosed				\$350,000	\$203,000 per unit
FUTURE RAIL GRINDING PROGRAM	Continue & upgrade condit. in switches & crossings	Continue & upgrade condit. in switches & crossings	Purchase small grinder in 1988	Continue & upgrade	Continue & upgrade	Continue & upgrade	Continue & upgrade	Not yet defined	As required

Summary of existing and projected rail grinding programs

ACCEPTANCE / PERFORMANCE STANDARDS

GRINDING FUNCTION

GRINDING REQUIREMENTS

- No. OF STONES
- No. OF PASSES
- MIN. METAL REMOVAL
PER PASS
- MAX. METAL REMOVAL
PER PASS
- ANGLE OF STONES
- PURPOSE

OPERATIONAL REQUIREMENTS

- PHYSICAL LOAD
CONSTRAINTS
- CLEARANCE CONSTRAINTS
- MAXIMUM GRADES
- MAXIMUM CURVES
- OPERATIONAL
CONSTRAINTS (ITEM 16)

CNR	GPR	B.C. Rail	Quebec, N.B. + Labrador	Cartier Railway	Ontario Northland	Algonia Central	B.C. Transit	Calgary Transit	Toronto Transit
Visual/gauge analyzer car	Visual/gauge analyzer car	Visual/gauge	Visual/gauge	Visual/gauge	Visual/gauge	Visual/gauge	Visual/gauge	Visual/gauge	Visual noise/vibration
Corrective	Corrective	Preventative on mainline corrective on switches and crossings	Preventative	Preventative	Corrective	No grinding	Corrective/ Preventative	Corrective 1987-1988	Corrective/ Preventative
Lease 120 stone Spino	Lease 120 stone Spino	44	36	24	Lease 120 stone Spino	No grinding	4 belts/ 12 stones	8	12 per unit
4/yr min. mainline	4/yr min. mainline	4/yr min.	782 pass miles (1258 km) in 1987	2200 pass miles (3540 km/yr)	2 pass/yr minimum		Continuous	Not determined	As required 4/yr min.
0.127mm (.005")	0.127mm (.005")	0.05mm (.002")	Not specified	Not specified	Not specified		Not determined	Not determined	Not specified
30" max.	30" max.	30" max.	20" max.	30" max.	30" max.		Not determined	Not determined	Not specified
Control corrug. maintain profile	Control corrug. maintain profile	Control defects maintain profile	Control corrugation	Control corrugation	maintain profile		Control noise levels provide good ride	Control roaring, rail provide good ride	Control roaring rail/vibration
Standard	Standard	Standard D.O.T.	Standard D.O.T.	Standard	Standard		5433 kg per axle	22,727 kg max. vehicle weight	
		2.28 mainline	8" mainline	7" mainline	Unknown		4520 vertical 1555 horizontal	3083 vertical 2500 horizontal	
		14" mainline	8" mainline	7" mainline	Unknown		6%	4.35%	
Availability of lease equipment & track time	Availability of lease equipment & track time	Minimal	Cold weather/ availability track time	Cold weather (-25°C)	No grinding in five season		80m R mainline 25m R yard	Max. 4 hrs./day track time	14" mainline Max. 4 hrs./day Non-revenue service hours

Summary of rail grinding criteria,
priorities and operational requirements

RAIL GRINDING MACHINE STUDY

UP-P-214

Table
2

3.1 Major Railroads

3.1.1 Canadian National Railway

CN Rail with a system length of 51,678 kms is Canada's largest railway. Their heavy haul regions are from Winnipeg to Thunder Bay and from Jasper to Vancouver. There are no load constraints for rail grinding equipment, and standard clearances are available throughout the system. Track time for grinding operations is not as constrained as the availability of grinding equipment. CN Rail have a regular grinding program based on the use of leased grinding equipment. In the mountain region in 1987, CN Rail used the Speno RMS-1, 120 stone machine (Figure 6) to make four runs between Jasper and Vancouver to remove corrugations and restore railhead profile. The RMS-1 stones can be angled to 30° and CN Rail were able to grind their rails to the desired profile pattern with this equipment. Grinding train personnel have suggested that one pass with the 120 stone machine after every 5 MGT, cutting 0.127 mm (.005") per pass would likely keep them in a preventative grinding mode. Curves which experience the most wear are problematic, and are difficult to maintain profile because of excessive wear and defect development. Subsequently, in 1987, CN Rail leased and later bought a 16 stone grinding unit from Fairmont Motors in an attempt to maintain the track conditions on curves to reasonably close conditions to the tangent tracks.

The amount of track time available for rail grinding varies throughout the year. If adequate track time (for instance in winter) coincides with availability of equipment, and the budget has been established, then the grinding can be accomplished with little difficulty. Conversely, if track time and equipment are not mutually available, the rail grinding program will suffer.

With regards to turnouts and crossings CN Rail began a grinding program between Edmonton and Vancouver in September of 1986. As of June 1987, the Fairmont RG-16 (Figure 7) had ground 341 switches and turnouts, 288 crossings and 69 curves. The average time required to complete grinding of a turnout was 45 minutes with 12 to 14 passes each. The average time to grind



Figure 6

Speno RMS-1



Figure 7: Fairmont RG-16

a road crossing was 25 minutes and would require 12 to 14 passes. This unit uses 152 mm diameter (6 in) stones of T and V grades to do all of this grinding.

CN Rail collect rail condition data visually with measurements by manual gauge and also utilize Speno's Rail Surface Analyzer Car "RSA" for measuring corrugation occurrence.

CNR are still in corrective grinding mode at this time. However, with the acquisition of the switch and crossing grinder and an active program for the 120 stone machine in 1988, they anticipate getting into preventative grinding in the near future.

3.1.2 Canadian Pacific Railway

In Canada, CP Rail operates a total of 34,010 kms of railroad. As with CN Rail their heavy haul regions are from Winnipeg to the Lakehead and in the mountains of British Columbia.

An example of a CP Rail heavy haul route is their unit coal train operation from the Selkirk Mountain mines to Roberts Bank Terminal over which each car grosses 176,000 kms per year.

CP Rail have a regular grinding program and an active research group which works in conjunction with CIGGT, NRC and the other railroad properties to identify and find solutions to the problems of track-train dynamic which accelerate corrugations and propagate defect growth in rails.

CP Rail also relies upon leased rail grinding services from Speno and Loram to meet their present rail grinding needs. CP Rail have recently leased a Fairmont RG-16 switch and crossing grinder for their 1988 program in an attempt to get these areas into condition. Most of the rail condition data is obtained by use of manual gauges although rail analyzer car equipment is now able to measure corrugation occurrence and depth.

In conjunction with CIGGT and the Transportation Development Centre, CP have issued the "CP Rail Grinding Field Manual". A copy of this manual is included as Appendix "A" and serves as an excellent reference illustration of their current rail grinding requirements. It should be noted that both corrective and preventative grinding are discussed in their manual.

Future rail grinding program of CP Rail is aimed toward getting into a preventative grinding mode in the near future.

3.2 Other Railroads

Other Canadian Railroad Properties with track systems of under 3000 kms experience the same track defect and wear problems as the two major railroads. A further problem faced by these smaller properties is the unavailability of leased rail grinding equipment during their peak grinding periods. With the introduction of the 100-ton car unit train operations, severe corrugations occur on their systems, and there was a lack of available rail grinding services on the market. The larger railroads have attracted larger contracts for the grinding train manufacturers. This has left the smaller railroad properties with little option. Most of these properties have now purchased rail grinding equipment and have been executing their own grinding program.

3.2.1 British Columbia Rail

BC Rail span the length of the Province with approximately 2846 km of track. The entire route can be considered a heavy haul region. Transport of timber products and grain from the north and coal from the northeast constitute the main business of BC Rail carrying 17 MGT in 1986. Maximum grade is 2.2% and the maximum curvature is recorded as 14°. Standard clearances are noted in this report and the catenary system used on the Tumbler Ridge Branch Line does not offer restrictions to their rail grinding equipment.

BC Rail purchased a Loram RGM-1 rail grinding machine in 1986, for approximately \$4.5-million. The RGM-1 as shown in Figure 8 has 44 grinding stones



Figure 8: Loram RGM-1

adjustable to 30° either side of the rail head. The machine is capable of grinding up to .127 mm (.005 in) per pass but is rarely required to make such cuts except on gauge corner when reprofiling of rails is required. Four passes per year for mainline track with extra passes on curves keep the rail in relatively good condition. Costs for this program are running at approximately \$700,000 per annum. Grinding programs are developed through careful visual inspections and manual measurements by use of gauges.

BC Rail are also involved with CIGGT, NRC and Loram on preventative grinding tests in North Central British Columbia. During these tests, wear measurements and profiles were taken, grinding patterns were tested and speed grinding tests were accomplished. All of this research development is aimed at a better understanding of rail/wheel interaction and associated track problems.

In 1988, BC Rail will be leasing a switch and crossing grinder and will attempt to bring the condition of this trackwork up to the mainline track conditions.

It is our understanding that BC Rail may purchase a light rail grinder in the future to complement their grinding program which by 1988 may be considered as preventative grinding.

3.2.2 Quebec North Shore and Labrador Railway

The Quebec North Shore and Labrador Railway system is 638 km in length. They haul both ore concentrates and pellets through curves of a maximum of 8°. In 1987 their volume was 37 MGT. Being a relatively short railroad they were unable to fit into the leasing programs provided by large equipment suppliers and therefore Quebec North Shore and Labrador have purchased a 36-stone Loram grinding machine in 1980. This one machine has been adequate for them to control corrugation growth in their system. Their grinding pattern is designed to match the rail head profile with the average worn wheel contour in their system. The 36-stones at 20 hp each can be

adjusted to 20° and apparently have been able to accomplish their profile pattern adequately. The cost of their program has been approximately \$348,000 per year averaged over three years.

Quebec North Shore and Labrador Rail have an independent system which does not interchange with other railroad properties. Such a system is beneficial in terms of the constant match of worn wheel to rail profile and a more compatible rail/wheel interface with less defect propagation.

Constraints to rail grinding on this system are availability of track time and the occurrence of high forest fire risk during summer months which sometimes hampers their planned program. Low winter temperatures also affect grinding activities. Grinding programs are developed around visual inspection of corrugation, wear and defect occurrences, and with the years of experience they have developed an efficient grinding and monitoring system for their property.

Quebec North Shore and Labrador Rail are in a preventative grinding mode on their mainline tracks. Switches and crossings are in a corrective grinding category at this time. Their future plans are to maintain mainline grinding, bring switches and crossings up to mainline standards and upgrade their grinding equipment to keep pace with their program.

3.2.3 Cartier Railway

Cartier Railway in Quebec have a 416 km system which handles iron ore concentrates (28 MGT in 1987). Their maximum curve is only 7° but they have 263 curves in the 416 km distance making it one of the more maintenance intensive railways in Canada (49% curves). They have no constraints to rail grinding except during the winter weather. In the winter of 1987/88, grinding operations were suspended when temperatures exceeded -25°C.

Cartier Railway have a regular grinding program made possible by their own rail grinding machine. The Company purchased a Loram prototype 24-stone grinder in 1976 and have upgraded the equipment since that time. The

24-stones are adjustable to 30° maximum and this is adequate to maintain rail profile according to discussions with their maintenance personnel. The maximum rate of metal removal per pass is .127 mm (.005 in) for this machine. Cartier Railway are able to grind 2200 pass miles per year to their own rail profile pattern and have claimed to have minimal corrugations in their entire system. It is interesting to note that Cartier Railway have purchased only low alloy head hardened rail supplied by the Japanese and British, with the average head surface hardness of 390 Brinell. They are in a preventative grinding mode and plan to upgrade their equipment and work on turnouts and crossings in the future.

3.2.4 Ontario Northland Railway

Ontario Northland Railway have a system length of 925 kms running from North Bay to Moosonee on James Bay. Although they experience corrugation to some extent, their main problem is curve wear and their grinding program is aimed at controlling this wear problem primarily with corrugations removed as required. Constraints to rail grinding are the forest fire season and the availability of lease equipment. Most grinding is accomplished during March and April, and in October, November and December.

Ontario Northland prefer to have a Speno RMS-12 (upgraded to 120 stone) make two passes per year to correct the rail profile and remove corrugations. Usually rail head condition is recorded in September by the Speno Analyzer Car and a rail grinding program is developed for October. In 1987 they leased a Fairmont RG-8 but were not able to complete their program as planned.

The future rail grinding program would be to maintain the status of the rail in current profile condition and address the wear and defect problems in switches and crossings.

3.2.5 Algoma Central

Algoma Central, with a system length of 518 kms, runs from Sault Ste. Marie to the north east serving the mining and timber industry in that area. The passenger tourist trade represents about 10% of their annual business. The Algoma Central have 1.7% grades and curves up to 12°. The annual tonnage is from 5-6 MGT and therefore, even though they have many heavy trains operating, it cannot be classified as a heavy haul freight property.

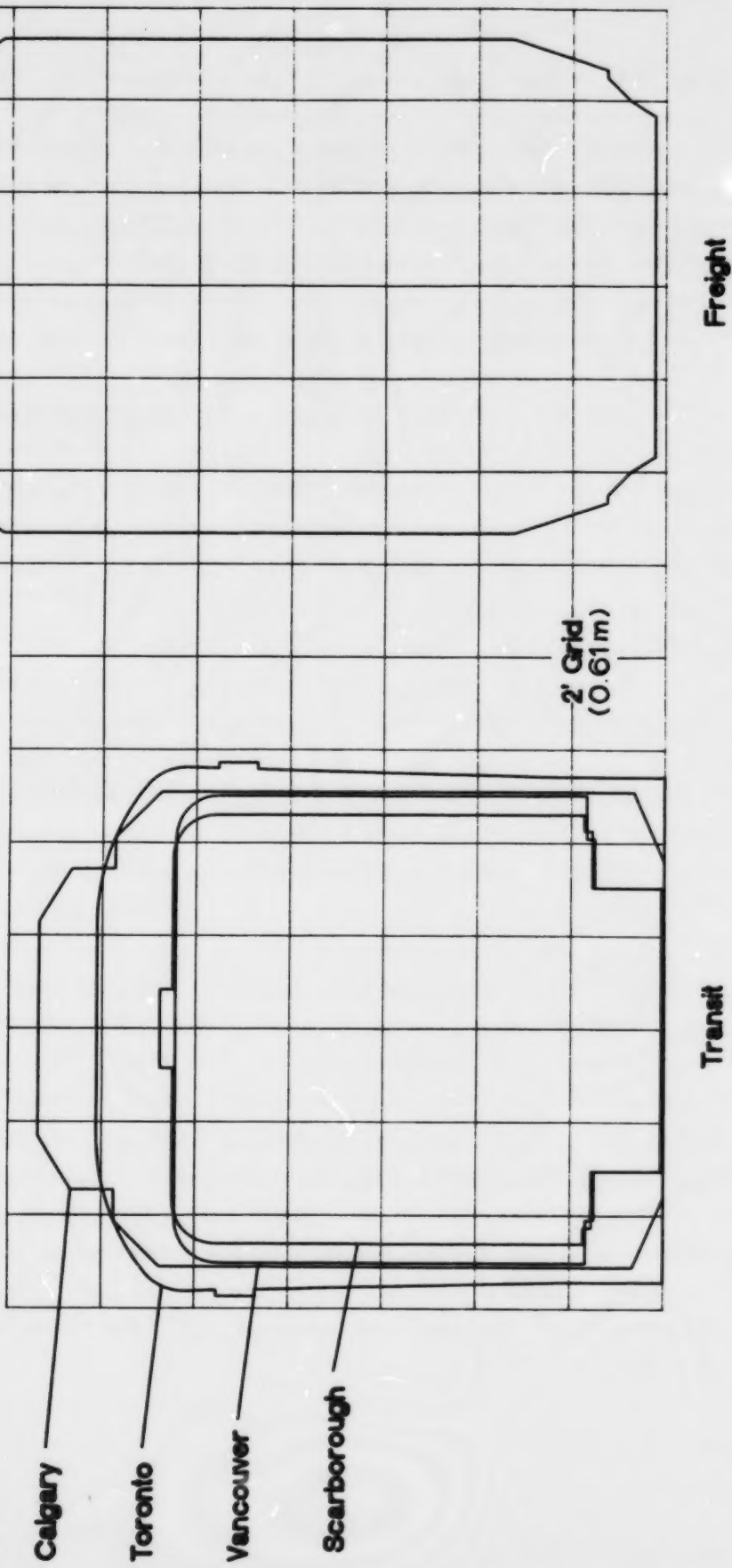
Algoma Central do not have a grinding program. Although subject to the same rail problems as other railways such as corrugations in excess of 1.27 mm (0.050 in), they do not have sufficient volume of business to warrant the cost of setting up and executing a rail grinding program. Rails are changed out when corrugations reach a depth of 2.54 mm (.100 in).

3.3 Transit Properties

3.3.1 British Columbia Transit

BC Transit's Skytrain is a light rapid transit system 22 kms in length consisting of mostly elevated guideway from New Westminster center to the waterfront in Vancouver. Maximum grade is 6% and minimum curve on the mainline is 70 m radius.

Operating constraints to rail grinding are indicated by the dynamic clearance diagrams as shown in Figure 9, which defines the limits of the linear induction motor rail in the center of the track, the ATC cable between LIM rail and running rail, and a power rail which is attached to an adjacent parapet wall. Track time is normally limited to two hours daily with four hours being the maximum work time available for rail grinding. Late in 1985 BC Transit attempted to have their new rails ground to remove surface imperfections and weld misalignments before commencement of revenue service. Existing grinding machines were ineffective and subsequently grinding equipments were designed and manufactured locally as shown on Figures 10 and 11.



Dynamic envelopes for various
transit and freight trains

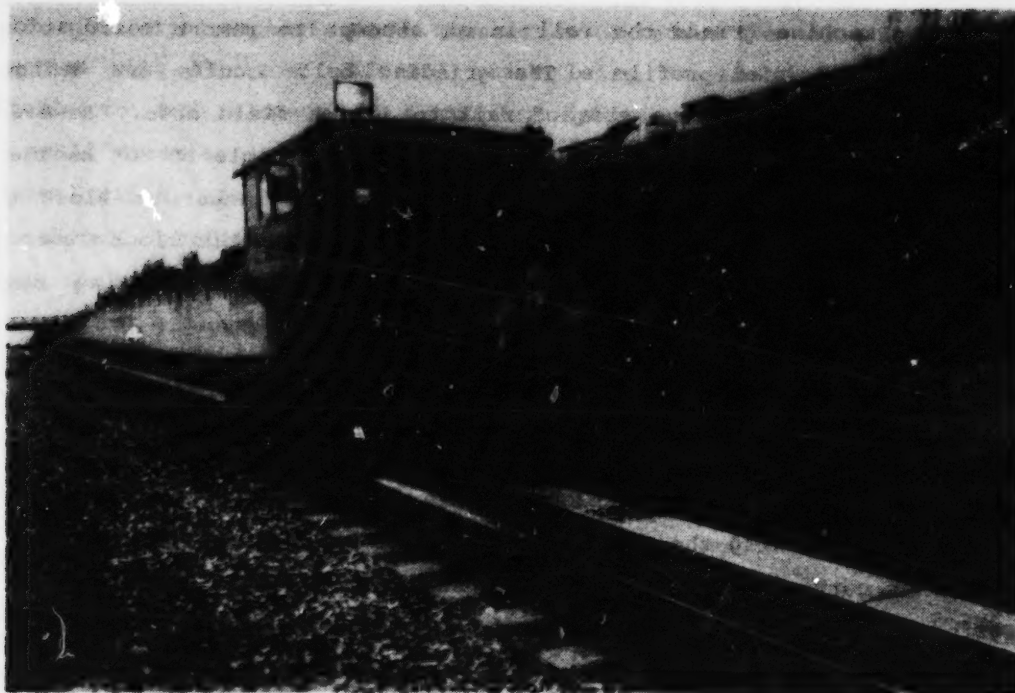


Figure 10: Gallant Belt Grinder



Figure 11: Block Grinder

BC Transit have a continuous rail grinding program in which a four belt grinding machine grinds the rail in an attempt to remove corrugations and maintain rail head profile. The grinding belt modules are designed to adjust from 50° on gauge side of rail to 10° on field side. However, the machine is considered efficient only to a maximum angle of 26° on the gauge side. This operation is usually followed by the linear or block grinder which is pulled over the rail at high speed. The static blocks wear to the profile of the rail head and then polish the rail removing remaining corrugation peaks and work hardened surfaces.

In field observations, it was noted that even with axle spacing of 2743 mm the belt grinder was not steering properly in tight radius curves evidenced by "squeal" and "chatter" noises. Close observation of the rail head at a low angle following the passage of the belt grinder indicates a very minor cross or corrugation pattern being induced on the rail head surface by the grind belt drive wheels. Although very aggressive grinding action takes place, very little metal is physically removed per pass. Study investigators on site were advised that it would require a minimum of 40 passes to remove .127 mm (.005 in) corrugations from the rail.

The block grinding module is adjustable to 7° from top center and in a recent test, 132 passes were made to remove a total of .17 mm (.007 in). The purpose and function of the block grinder is not for metal removal but for removing surface roughness and lowering the noise level.

BC Transit intends to continue operating the block and belt grinders as part of their preventative grinding program. Alloy rails have been ordered for their future extension to Surrey and are expected to reduce the extent of rail corrugations experienced on their existing system. Track stiffness has also been attributed to have caused rail corrugations. Impact loads are higher for stiffer tracks and considering the small diameter wheels can cause high contact stresses on the rails. A more resilient fastener has been ordered for the extension project. Research and development work on the steerable trucks is ongoing to reduce the frictional resistance of the wheel/rail interaction. Rail profile grinding has reduced the amount of

corrugations on curves and squealing noise resulting from wheel/rail interface. The major emphasis of BC Transit is to reduce the noise level on their system with the most difficult task being to isolate the causes attributable to each element of a complex system encompassing steerable trucks, small diameter wheels, tight radius curves, stiff fasteners, soft carbon steel rails, LIM reaction rail driven by electromagnetic forces and worn wheel/rail profile interface. A rail profile grinder that can accurately control the pattern of grinding and fit within the constraints of the guideway and guideway elements will help to improve the present grinding program.

3.3.2 Calgary Transit

The Calgary Transit system is 26 km in length consisting of about 1 km of in-street trackwork, about 2 km of direct fixation trackwork and the remaining on ballasted concrete ties.

This system being more conventional, in terms of light rail design with overhead catenary than the BC Transit Skytrain system, lends itself to more available grinding equipment fitting within the operating envelopes as shown on Figure 9. Calgary Transit have experienced typical transit track corrugations, of short wavelengths, defects and wear problems, but until 1987, did not have a regular grinding program. In August of 1987 Calgary Transit purchased a Fairmont RG-8 spot grinder. A program of corrective grinding was immediately undertaken and preliminary reports indicate that the grinding machine is very effective on their track system. The RGH-8 is able to grind to an angle of 45°, which allows it to grind gauge corner profile. The ability to use 101 mm (4 in), 152 mm (6 in) and 254 mm (10 in) diameter grinding wheels allows the unit flexibility in grinding crossings, switches and in-street trackwork.

Calgary Transit remains in a corrective grinding mode but anticipates moving into a preventative mode in the near future by implementing an aggressive grinding program through 1988.

3.3.3 Toronto Transit Commission

Toronto Transit have a system length of 175.7 km (109.8 miles). Maximum grades are 4.5% and maximum curves are 120 m. Toronto Transit have a regular grinding program which attempts to control roaring rail corrugation, prevent excessive vibration and noise and slow the regrowth of these unwanted conditions. Constraints to grinding are clearances as shown on Figure 9. Non revenue service times are short but are the only periods in which grinding can be accomplished.

Linear grinders (block grinders) are used to dress the rail head. Profile grinding is not possible with such equipment. Three grinding machines, one supplied by the Japanese and two manufactured locally, are used to grind the system on a quarterly basis, with tight curves getting more passes as required. The grinding machines have six grinding blocks per rail and are pulled by a traction unit. Capital cost of these units is approximately \$203,000 each and an annual labour charge for rail grinding has been estimated at \$33,000.00.

With this equipment, Toronto Transit is not able to perform rail profile grinding and has not been able to remove sufficient metal per pass. In future grinding programs, these problems will need to be addressed. Their option, as in Vancouver, is limited by the unavailability of grinding units that can fit within their operating envelopes.

4.0 STATE OF THE ART OF RAIL GRINDING TECHNOLOGY

Documentations on rail grinding technology are presented in this section. Rail grinders are categorized by:

- Heavy grinding machines (Figure 12);
- Light grinding machines (Figure 13).

4.1 Heavy Grinding Machines

In North America, Australia and Europe the typical rail grinder is a rotary grinding wheel mechanism which features self-propulsion units with ample power, fuel and water contained within the unit. Travel speed is in the 40 - 100 km/h range, and work speeds up to 4.8 km/h are common. Grinding modules are mounted on a supporting framework which also houses typically 10 to 20 hp electric or hydraulic motors. Vertical spindles attach the grinding wheels to the supporting framework. These wheels are cylindrical shape and of nominal 63 x 152 x 254 mm in dimensions. Depending on the size of the grinding train some of the modules will be in fixed angle positions to address the basic profile requirements, while other modules are adjustable as required to "dress" the rail head. The operating environment of rail grinders is extremely dirty, and designing systems which function efficiently in this environment is one of the great challenges facing the industry. Electrical systems (motors) perform well, are readily available, and are robust, but are generally large and heavy. Hydraulic systems are also used for grinding wheel drive and control. Hydraulic motor and control systems also perform well and are comparatively small, but are subjected to a harsh environment and at times are problematic during operations. Hydraulic hoses and fittings can break under operation. Hydraulic oil leaks compound the problem with maintaining the equipment. In hot weather the flammable nature of some oils, and in cold weather the gelling and freezing point of hydraulic oils are an operational nuisance on a high production expensive grinding machine. The advent of phosphate ester-fluids and water-glycol mixtures, which are fire resistant, have helped in this area.

Reid Crowther

MODEL	Fairmont RG-40	Loram LRT	Loram SPM-1	Loram RGM-1	Speno RMS-2	Plasser Theurer SDM-200
SPECIFICATIONS						
LENGTH mm	44,653	26,212	26,200	95,433	190,500 (625')	18,900
WIDTH mm	2438	2743	2743	3251		2500
HEIGHT mm	3467	3302	3302	4724		3680
WEIGHT kg	490,600	63,636	64,504	187,272		60,000
RAIL GAUGE mm	1435	1435	1435	1435	1435	1435
AXLE SPACING mm		5486	5940	2743		
WHEEL Ø mm(in.)	724 (28.5")	610 (24")	610 (24")	724 (28.5")		710 (28")
POWER	DIESEL	DIESEL	DIESEL	DIESEL	DIESEL	DIESEL
PROPULSION	SELF	SELF	SELF	SELF	SELF	SELF
FUEL CAP. litres	5625	1575	1593	18,000	63,000	
WATER CAP. litres	18,000	2700		90,000	198,009	
SPEED km/h	60	48	48	60	100	80
# OF OPERATORS	2	2	2	2-4	9	2
CARRIAGES	5	3	5	3	5	1
MODULES	25	3	5	44	5	Planer
# OF STONES	40	24	40	44	120	
STONE SIZE mm	254	254	254	254	254	
STONE GRIT	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D	Planer
STONE DRIVE	ELECTRIC	ELECTRIC	ELECTRIC	ELECTRIC	ELECTRIC	
STONE CONTROL	MECHANICAL	HYDRAULIC	HYDRAULIC	HYDRAULIC	MECHANICAL	
ANG. ADJUSTMENT gauge / field	30°-0°-30°	30°-0°-30°	62°-0°-62°	30°-0°-30°		68°-0°-68°
# OF BELTS						
BELT GRIT						
WORKING SPEED km/h	4.8	3.2	4.8	3.2-4.8	4.8	20-80 m/min.
METAL REMOVAL PER PASS	ADJUSTABLE	ADJUSTABLE	ADJUSTABLE	ADJUSTABLE	ADJUSTABLE	ADJUSTABLE

Heavy rail grinder comparison chart

RAIL GRINDING MACHINE STUDY
UP-P-214

Figure
12

MODEL SPECIFICATIONS	Gaillard Beaver (Belt)	Grindhills (Block)	Fairmont RG-8	Fairmont RG-24	Loram SX-16	Jackson Jordan SCG-23
LENGTH mm	3657	3784	6400	21,954	12,192	12,192
WIDTH mm	2600	1651	2600	2438	3251	3124
HEIGHT mm	2590	1905	3400	3467	3810	3810
WEIGHT kg	6818	9227	13,608	27,909	36,288	36,240
RAIL GAUGE mm	1435	1435	1435	1435	1435	1435
AXLE SPACING mm	2743	2222	3000			6451.6
WHEEL Ø mm(in.)	406 (16")	508 (20")	610 (24")	724 (28.5")	610 (24")	724 (28.5")
POWER	DIESEL		DIESEL	DIESEL	DIESEL	DIESEL
PROPULSION	SELF	BY LOCOMOTIVE	SELF	SELF	SELF	SELF
FUEL CAP. litres	225		4731	1575	1514	2025
WATER CAP. litres		1800	1230	9000	3024	4500
SPEED km/h	30	40	56	40	40	80
# OF OPERATORS	2	2	1	2	1	1
CARRIAGES	1	1	1	3	2	3
MODULES	4	4	4	15	2	16
# OF STONES		12	8	24	16	16
STONE SIZE mm		76.2x101x254	AS REQ'D	254	254	152 OR 254
STONE GRIT	36-40	VARIOUS	AS REQ'D	AS REQ'D	AS REQ'D	AS REQ'D
STONE DRIVE	ELECTRIC		HYDRAULIC	ELECTRIC	ELECTRIC	HYDRAULIC
STONE CONTROL	HYDRAULIC	MANUAL	MECHANICAL	MECHANICAL	HYDRAULIC	HYDRAULIC
ANG. ADJUSTMENT gauge / field	50°-0°-10°	7°-0°-7°	45°-0°-45°	30°-0°-30°	30°-0°-30°	45°-0°-45°
# OF BELTS	4					
BELT GRIT	30-40					
WORKING SPEED km/h	3-5	40	4	4.8	6.4	3.2
METAL REMOVAL PER PASS	.26mm AVG.	ADJUSTABLE	ADJUSTABLE	ADJUSTABLE	ADJUSTABLE	ADJUSTABLE

Light rail grinder comparison chart

Grinding wheel technology (13) is adequate for machines moving at working speeds of 3 to 5 km/h. The use of zirconia alumina abrasives have increased efficiencies of grinding wheels over standard aluminum oxide wheels. The future needs of higher working speed grinding machines will dictate the advancement in abrasives and in bonding systems.

With regard to grinding wheel technology, abrasives and bonding are still under ongoing research and development. With the introduction of zirconia alumina abrasives there has been a great increase in the life of grinding wheels. Organic bonding resins are slightly resilient and melt at approximately 400°F which makes them efficient in metal removal on most rails. The grade of a grinding wheel or stone refers to relative amount of grit and resin and therefore is a indication of the hardness of the stone or wheel. Grades are from A to Z, "A" being all grit and "Z" all adhesive. An "O" grade wheel would be used for hand grinding. Grades from "Q" through "V" are commonly used for machine rail grinding.

Instrumentation and control are advancing rapidly to meet the new rail grinding requirements. State of the art grinding machines are being developed now which will be interactive with the measurement of rail profile, corrugation occurrence and severity, using on-board equipment. The information can be analyzed and grinding modules automatically adjusted by computer to a pre-selected rail head profile. The economy of these systems will improve overall grinding efficiencies as they are developed. At this time rail profiles are measured by hand using profilometers and other gauges (Appendices B and C), while the major heavy haul properties employ rail surface analyzer cars. The rail analyzer equipment is still in the development stage and at this time is only efficient in supplying data on corrugation occurrence, severity and rail defects such as breaks and shells.

Several manufacturers of rail grinding machines are currently testing rail head imaging systems such as the ORWIS (Optical Rail Wear Inspection System) and the LITESLICE system. Both systems employ a light source to illuminate a "slice" of the rail section to be measured. The systems do not contact

the rail. The ORWIS uses a single video camera aided by reflecting mirrors to capture the profile of the rail head. It is currently being tested by Speno Rail Services on CN Railway's test car. The LITESLICE system was developed for the Hammersley Railway in Western Australia. This system utilizes two video cameras over each rail and captures the complete profile of the rail section. Apparently Conrail installed this system on an analyzer car in 1986 and are satisfied with the accuracy of measurement obtained.

Large rotary grinding machines range from 26 to 190 meters in length; widths from 2.4 m to 3.3 m, and up to 4.7 m in height, measured from the top of the rail. Gross weights of these large grinding trains are acceptable on freight railways but not on transit systems. All machines surveyed are self-propelled and typical motive power is provided by diesel engine through multiple drive axles and standard wheels ranging from 610 to 724 mm diameter. Water capacities vary from the smaller machines up to 1500 litres. The larger trains can tow complete water tank cars of 198,000 litres with the machine. Fuel capacities range from 1600 - 63,000 litres.

The "rail planer" system as developed by Plasser and Theurer is now being used in Britain, Brazil and Australia. This system of rail planer and swarf-collector is considered an efficient tool for totally re-profiling badly worn and defective rail, but not as a preventative grinding system. (Appendix D).

4.2 Light Rail Grinders

Transit systems have small radius curves, steep grades, and limited clearances which therefore require light weight, short wheel base machines which are capable of removing corrugations, removing defects and re-profiling the rail head. Depending on trackwork configurations in the various systems investigated and their needs, linear (block) grinders, belt grinders and small rotary spot grinders have been used successfully, and are described below:

- Linear Grinders

Linear grinders are rail polishers and are typically 4 m in length, minimum. The "Grindhilda" on the Skytrain system in Vancouver is 1651 mm wide and 1905 mm in height. Block grinders are not self-propelled but are towed by an available traction unit. In Vancouver, 12 static grinding blocks are fixed into position with 6 on each rail. The stones adopt the shape of the rail head when they are pulled along the tracks. The machine weighs 9 - 10,000 kg.

- Belt Grinders

To our knowledge, the belt grinding technology has been developed only for the Vancouver Skytrain system. This machine is 3.6 m in length, 2.6 m wide and 2590 mm in height. Axle spacing is 2743 mm and wheels are 406 mm (16") diameter. It is a self-propelled machine, diesel powered, with a fuel capacity of 225 litres and a travel speed of 30 km/h. It has four belts and has a working speed of 3 - 5 km/h. Average metal removal rate is given as .26 mm per pass. Based on our observations, this grinding machine will require some technological improvements before it can be considered a production type machine.

- Rotary Grinders

Small rotary stone grinding machines available today are advertized as "spot grinders" or "switch and crossing grinders". Machine lengths vary from 6.4 m (RG-8), 12.1 m (Jackson-Jordan SCG-23 Loram SX-16) to 26 m (Loram LRT). Widths range from 2.4 m to 3.2 m, and heights are typically 3.4 - 3.8 m. All rotary grinding machines surveyed were self propelled and grinding modules either electric or hydraulic powered. Grinding stones in three diameters are normally used (101, 152 and 254 mm). Travel speeds of 40 - 60 km/h and working speeds of 4 - 6.4 km/h are common. Machine weights range from 13 - 36,000 kg and stone angular adjustment to 45° each side of rail is typical.

TABLE 3 - SUMMARY OF COSTS

Rail Grinding Machine	Contract Lease Price	Purchase Price
● Speno RMS-12	\$1950.00/hour	--
RMS-13	1885.00/hour	--
RMS-1]	2340.00/hour	--
RMS-2]		
● Loram SP-88	\$1725.00/hour	--
SX-16	4600.00/day	
● Fairmont RG-24	\$552.00/hour grinding	
	415.00/hour standby	
RG-16	578.00/hour grinding	
	318.00/hour standby	
RG-8	422.00/hour grinding	\$400,000.00
	240.00/hour standby	
● Jackson Jordan		
SCG-16 (20 Stone)	\$4500-\$4700/day	\$1.1 Million
● Gallant Belt Grinder		\$80-\$100,000.00
● Grindhilda Block		
Grinder		\$40-\$50,000.00

4.3 Costs

Modern rail grinding equipment can be contract-leased or purchased outright. For the larger grinding units, lease contracts typically provide for the grinding train, crew, accommodations, expendables and fuel and is based on a 10-hour day minimum charge. Smaller grinding machines are normally rented by the hour based on actual grinding time and a standby rate. The supplier usually provides crew and spare grinding wheels, but mobilization, demobilization, fuel and water are usually the responsibilities of the leasee. Taxes are usually not included in the lease agreements.

Both CN Rail and CP Rail lease heavy rail grinding equipment. Due to their high volume of work, they have reasonable assurances that the equipment will be available when required. Smaller railroad properties such as Cartier Railway, Quebec North Shore and Labrador and BC Rail have purchased equipments which give them the flexibility of setting their own grinding programs to meet their requirements.

Individual Railroad and Transit properties have specific requirements in rail grinding machines. Therefore purchased equipment is usually subjected to custom manufacturing, which accounts for the varying purchase prices.

The following table is a summary of leased and purchased costs for rail grinders expressed in Canadian dollars.

5.0 ALTERNATIVE RAIL GRINDING PROGRAM

5.1 Preventative Grinding

From our investigations into the trends of rail grinding and the state of the art of rail grinding technology, we have identified that a preventative grinding program, based upon the utilization of light weight rail grinders, best meets the needs of railway organizations in North America for the following reasons:

- Major railroad properties

Due to the length of their systems, these properties will continue to require large grinding trains to do corrective grinding on the basis of multiple trips per year. Switches, crossings and other special trackwork structures, and also tight curves which experience heavy wear and loading, will require the use of small efficient grinding machines to maintain these areas in conjunction with existing track maintenance programs.

- Other railway properties

Even with their current positions of preventative/maintenance grinding of mainline rails, they will need to grind other trackwork on a regular basis. Large grinding machines are not able to function in special trackwork and crossings. Smaller rail grinding machines will be needed.

- Transit properties

Especially transit systems with third rail power pickup, tight curves and short track maintenance periods, rail grinding programs cannot be serviced by existing large and medium rail grinding machineries.

5.2 Technologies

The three existing small rail grinding systems in various stages of development at this date are as follows:

- The Linear grinding machine (or block grinder)

This machine has relatively small dimensions typically less than 4 m in length, 1.6 m wide and 1.9 m in height, assuming that the machine is not self-propelled. As discussed in Section 4, the block grinder has certain advantages but is not capable of rail profile grinding and is inefficient for removing corrugations and defects. The ability of the block grinder to polish rail head to reduce noise level is well accepted. Therefore in certain transit systems, it has a definite application.

- The Belt Grinder

This machine has relatively small dimensions and is compatible with most transit clearances. The Gallant belt grinder is 3.6 m in length, 2.6 m wide and 2.6 m high and therefore meets most space constraints found in transit systems. The belt grinding concept is viable but there remains considerable development work required to make the machine into an efficient rail grinder, especially in the areas of metal removal, tracking in tight curves and in its ability to grind to desired rail profile.

- Rotary grinders

These machines, which are currently being manufactured by three companies best meet the majority of performance requirements of an alternative rail grinding machine.

5.3 Rotary Stone Rail Grinding Machine

The small rotary stone rail grinder is the machine that best meets the preventative rail grinding requirements of railroad and transit properties. An example of the acceptance of small, fast rotary grinding machines is the Fairmont RG-8 "spot grinder". In the past 18 months, Calgary Transit have purchased one unit, CN Rail two units (RG-16), CP Rail have two on lease (RG-16), and Burlington Northern have purchased two RG-8 units, and has four more on order. The Loram SX-16 and Jackson Jordan's SCG-23 (20 stone) switch and crossing grinders are leased to railroad properties and are in constant demand.

As a result of our investigations, we feel that the small rotary grinder, constructed as modular self-propelled units featuring short wheel base dimensions, having small diameter grinding stone mounting capabilities, small diameter wheels, high speed functions and the ability to grind efficiently in tight curves, in-street trackwork, turnouts and crossings is the preventative grinding machine that will be most sought after.

5.4 Performance Requirements

5.4.1 General

The Rail Grinding Machine should be a modular unit capable of profile grinding of rail head on 1435 mm gauge trackwork systems consisting of tangent track, turnouts, crossings and tight curves. The basic module should efficiently couple to other identical units to increase the work output of the machine. The machine should have the capability of rapid travel between sidings and worksites and have a high working speed. The machine should have dimensions which are compatible with dynamic envelope configurations of trackwork and guideway structures existing in North America. The machine should have the ability to grind rail in either forward or reverse direction and be highway transportable.

5.4.2 Dimensions and Weight

The rail grinding machine should work effectively within the dimensions governed by clearance diagrams of the smaller dynamic envelopes. A vehicle of the following dimensions would appear to fit the operating envelopes of most North America transit properties:

- Width 2600 mm maximum
- Height from top of rail 3067 mm maximum
- Width of grinding module
carriages or devices 1800 mm maximum
- Length dimension should contain 8 grinding modules and accommodate rail head imaging equipment at both ends of the frame. Estimated minimum length is 7ms.
- Wheel base 3000 mm maximum
- Weight range 12 - 14 tonnes

5.4.3 Machine Components

5.4.3.1 Axles and Wheels

Depending upon vehicle configuration (see 5.4.3.12) the grinding machine would have 2 or 3 axles. The two drive axles would be designed to attach to the vehicle framework in such a manner as to maintain the lowest practical vehicle height. The axles should be standard axle shafts and wheels of 610mm maximum diameter. A grinding machine which is purchased should have the wheels custom machined to match the customer's rail head profile.

5.4.3.2 Brakes

The brake system chosen should be of fail-safe design. If air brakes are used the compressor should be mounted on and driven by the main propulsion engine. Brake systems must be protected from the metal dust atmosphere and be easily accessible for inspection and maintenance.

5.4.3.3 Propulsion

A rail grinding machine works in an excessively dirty environment. It is necessary to provide adequate propulsion power and also to protect the system properly. The propulsion system must function efficiently within a temperature range of -30° to $+50^{\circ}\text{C}$. The main propulsion unit should be a Diesel Engine of 450 - 600 hp capacity to move the fully loaded machine at travel speed (60 km/h) and to power the machine working at 11.2 km/h. The propulsion unit should be housed in a dust proof, sound deadened compartment complete with an efficient air movement system. For cold weather operations the main engine should be equipped with coolant heaters, crankcase heaters, fuel line heaters and other starting aids. This engine should be located on the mainframe at the opposite end from the cab and should be kept as low as possible to minimize the overall height of the machine.

5.4.3.4 Power Supply

The power supply for grinding modules must operate in a hostile environment and must, therefore, have the same protection and operating conditions as for the main propulsion system. In the case of a hydraulic grinding motor machine the hydraulic pumping and control system would be connected to and powered by the main propulsion diesel engine (450 - 600 hp). If electric motors are used a generator set of sufficient capacity must be housed in a compartment equivalent to the main propulsion engine housing.

5.4.3.5 Electric

A Generator for supply of energy for grinding motors and auxiliary needs should be of sufficient capacity, and be equipped for cold weather starting and easy maintenance. This unit should be housed in the main engine compartment to take advantage of environmental protection and sound insulation.

5.4.3.6 Hydraulic

Hydraulic systems should be of heavy service design with sufficient reserve capacity to continue operating in a hostile environment. Hydraulic oils should be of high flash point values, and consideration should be given to the use of phosphate-ester fluid or water-glycol mixtures which although comparatively expensive, are efficient and fire resistant. Solid piping should be used for the hydraulic fluid system as much as possible and highest quality flexible hose used to connect rams and motors. Careful consideration must be given to protection of hydraulic systems from metal dust and heat damage.

5.4.3.7 Grinding Modules

Our investigations have identified the requirement of grinding the rail head, not only to ease the gauge corner contact on high rails in curves and restore desirable head radius, but present a gauge face on the high rail which is compatible with the contour of the "average worn wheel". To do this, the grinder must be able to grind at an angle of 75° from top centre of rail head on the gauge side. An angle of 45° on the field side is adequate to remove metal lip if desired. It is essential to have full power rating of grinding motors available to the work in order to accomplish metal removal efficiently. Grinding modules should be constructed with the precision and structural strength of machine tools so that they can be infinitely adjusted and have the strength and rigidity to cope with

rotational and directional forces imposed upon them which are characteristic of high speed grinding. There should be a total of eight (8) grinding modules per unit positioned as close to the drive axles as possible, in order to maintain accuracy. The grinding modules should be infinitely adjustable between 75° gauge side and 45° field side of the rail. The grinding wheels should be driven either electrically or hydraulically and have sufficient output to provide 20 hp to the grinding wheel at maximum working speeds or when negotiating grades. Angular adjustment would be from the control cab of the vehicle. The adjustment should be positive and easily accomplished without use of sophisticated electronic devices.

The grinding modules should have long wave controls which will prevent grinding in corrugation valleys while providing full working horsepower to the device on the corrugation peaks.

To prevent damage to the grinding modules and the rail the grinding machine should have an automatic retracting mechanism which lifts the grinding modules when the machine slows down, stops or reverses direction of travel. The grinding machine should have a system of individual module control which raises grinding stones or belts in sequence to allow for precision grinding in turnouts and crossings. Grinding stone replacement should be easily accomplished by provision of easy access and simple attachment devices on grinding motor shafts.

5.4.3.8 Grinding Wheels

Efficiency in metal grinding is a function of grit type, shape and hardness, and bonding material. Rate of wear depends on these ingredients, plus rotational speed of wheels or belts and speed of vehicle. As the requirement for higher speed grinding becomes prominent it is important to communicate with suppliers who are continually researching grinding wheel technology.

Grinding wheels should be matched to grinding modules which will accommodate wheels in the range of 101.6 mm to 254 mm diameter, and meet industry standards as set by CSA B173.5-1979. Grinding wheel grades should be matched to rotational speed and the type of rail material being ground, typically from "Q" through "V" grades. The rotational speed, pressure and work speed of the vehicle should be matched to stone grade to avoid thermal damage to the rail.

5.4.3.9 Metal Removal

It has been observed that the efficiency of metal removal drops as the speed of the grinding machine increases up to a speed of 9.6 km/h (6 mph) , at which point the metal removal rate remains reasonably constant up to the speed of 16 km/h (10 mph).

The rate of metal removal from the rail should be a minimum of .05 mm (.002 in) per pass at maximum working speed of 11.2 km/h (7 mph) for an 8 stone grinding machine with full 20 horsepower grinding motors.

5.4.3.10 Dust/Dirt Control

Trackwork arrangements such as depicted in Figure 9 demonstrate the proximity of power rails to running rails in a representative sample of transit systems. The noted power rail is sensitive to metallic dust particles.

The grinding machine should have skirting apparatus, preferably metal housings, to effectively control sparks and metal debris from damaging other trackwork components.

5.4.3.11 Fire Control

Fire is one of the main hazards of rail grinding. Wooden crossties, wooden timber trestles, wooden grade crossings, grasses and shrubbery, along with wood preservatives and rail lubricants form a hazardous environment.

Complete containment of sparks and hot metallics causes excess heat in grinding module areas which damages hydraulic and electrical components, whereas minor containment allows hot sparks to ignite adjacent shrubbery and grasses. A balance must be achieved in design of skirting and placement of waterspray devices to best control fires.

The grinding machine should have water spray bars located at each end of the vehicle to provide fire protection for wooden ties, grass and shrubbery adjacent to the track. Water storage capacity should be 1400 litres minimum for the 8 stone machine.

5.4.3.12 Cab and Controls

The cab should be designed and constructed to provide good visibility of the work area in forward or reverse directions of travel. The cab should have approximately 4 square meters of floor area, have 2.9 m headroom, be air-conditioned, dust free, meet OSHA noise level requirements, and offer comfortable arrangements for two operators. Cab windows should be of standard tinted safety glass. The control mechanism should provide independent horsepower and angle adjustment to individual grinding modules. All other adjustments of modules should be easily accomplished from the cab. If the cab location, mounted on top of the vehicle main frame, projects beyond practical limits imposed by clearance restrictions, a cab mounting which is independent of the main frame should be considered. In such a configuration, the cab would be lower than the main frame and would likely incorporate a small supporting axle on small diameter wheels. This axle might be steerable, pivoting on vehicle centerline and thereby avoid steering problems in small radius curves.

5.4.3.13 Safety Equipment

The grinding machine should have cab-mounted fire extinguishers of adequate type and size, and each outside corner of the machine should also be equipped with extinguishers. An industrial first aid kit should be located in the cab. Pressurized spray water system with hoses for fire control should be provided.

5.4.3.14 Couplers

The grinding machine should have standard AAR couplers compatible with existing systems in use in North America.

5.4.3.15 Rail Head Measuring Equipment

Rail head condition is determined by visual examination and measurements made by manual gauges. Wear, defect occurrence, frequency and depth of corrugations are then recorded and are the basis of the resulting grinding program. Optical rail wear devices have been designed which measure and record these data. It is our opinion that such time-saving devices will form an important function in the next generation of grinding machines.

The framework of the grinding machine should be constructed to accommodate rail head profile measurement devices such as the ORWIS system, the ORION system, or a laser measurement system which could be optional equipment with the grinding machine. Provision should be made in the cab for instrumentation modules compatible with this equipment.

5.4.3.16 Optional Equipment

The following items should be available as optional equipment:

- rail head profile measuring and recording system;
- grinding motor control system;
- tool and equipment storage compartments;
- rail sanders (for traction);
- auxiliary water pump and hoses.

5.4.3.17 Maintainability

The grinding machine should be constructed to allow access to all component parts to provide easy maintenance access for non-technical work crews. Adequate storage for tools, oils, greases and grinding wheels should be provided.

5.4.3.18 Replaceability

All component parts of the grinding machine should be incorporated in the design and construction of the unit so as to provide access for easy replacement. Standard "off the shelf" components should be incorporated in the construction as much as possible.

5.5 Equipment and Costs

A summary of the equipment cost breakdown for materials only is shown below:

	<u>Costs</u>
● Cab and chassis, complete with insulated, sound deadened and filtered engine compartment, fuel, hydraulic oil and water tank	\$30-50,000
● Main propulsion engine. 8 cylinder diesel of approximately 500 hp capacity, complete with hydrostatic drive system and hydraulic pump and systems	\$60-100,000
● Electric generator for auxiliary power, 35-40 kilowatts capacity	\$10-20,000
● Hydraulic motors, controls, piping, hoses and fittings, plus hydraulic rams and fittings	\$20-50,000
● Computer control system (estimated)	\$20-50,000
● Miscellaneous materials including spark aprons, lights, water piping, electrical cable, breakers and fittings, storage and tool boxes and unidentified items	\$10-30,000
● Rail head imaging system	\$250,000 - \$300,000/unit
● Assembly costs for prototype construction and testing would be in the order of	\$300-500,000

5.6 Rail Head Imaging and Grinding Wheel Control Technology

During the process of the rail grinding machine study, it has become evident to project investigators that data gathering, processing and grinding module control areas are not advancing efficiently compared to other mechanical component design and manufacturing aspects of rail grinders. We have investigated the possibility of developing a rail head imaging system and an advanced grinding wheel control system in Canada. This would be available as optional equipment or standard equipment on new machinery.

5.6.1 Railhead Profile Monitoring System (RPMS)

Component parts of the RPMS are as follows:

- vision system;
- image processing system;
- analysis system.

The vision system would provide the initial image of the rail head. There are currently on the market systems which use a line of high intensity light focused on the railhead and a pair of video cameras focused on the railhead to generate the initial image. A more efficient approach would be to use a scanning laser and linescan cameras to generate the initial image. This combination should give a more precise image and be capable of much higher update rates than a standard video camera, thus giving a much greater number of images per length of track at any given speed.

In a fully configured system there would be two vision systems. One mounted in front of the grinding wheels to give the initial profile of the railhead. The second vision system would be mounted after the grinding wheels to give the final profile of the railhead.

The image processing system would take the inputs from the linescan cameras, combine and process them, and generate an image of the railhead profile.

The functions of the analysis system would depend on an assessment of the customer's requirements and the interface required to the Grinding Wheel Control System. Some functions which this system could perform are statistical analysis of the condition of sections of rail relative to an ideal profile; presentation of a visual image of the railhead; generation of appropriate control outputs to the GWCS; generate assessments of the number of passes required to return the railhead to an optimum profile; and perhaps even generate an assessment of the expected life of the rail between grindings.

5.6.2 Grinding Wheel Control System (GWCS)

The concept for the GWCS design is that it would be a computer-based system using off-the-shelf components and custom developed software.

Currently available systems appear to control only the pressure of a grinding wheel on the rail. The GWCS also incorporate positional sensors on the grinding wheel mounts. These would allow the GWCS to accurately position the grinding wheels and provide an indication of the wear on a grinding wheel as grinding progresses.

The GWCS would receive the actual railhead profile from the first vision system of the RPMS and compare it to the desired profile stored in memory. Based on the discrepancy between the two profiles, the GWCS would assign an initial position to the grinding wheels to generate the desired profile. The image from the second vision system would be used to provide the feed back necessary to ensure that the desired profile is being achieved. It would also allow the GWCS to compensate for variables such as wear on the grinding wheels as the grinding operation progresses.

With the type of control system envisioned, it would be possible to automatically adjust the number of grinding wheels actually in use at any one time based on variables such as the amount of metal which must be removed and the speed of the grinding train. This should increase the life of a set of grinding wheels considerably over a system which has all the grinding wheels in contact with the rail all the time.

A local Research Development and Manufacturing Company have assisted in the preparation of the costs and schedule as shown below.

RPMS

● Conceptual design and production of a model	4 months
● Prototype design, building and testing	3 months
● Manufacture of first production unit	1.5 months
● Field test production units	2.5 months
● Modifications and re-testing	1 month
● Estimated cost of materials and labour	<u>\$260,000.00</u>

The development program for the GWCS would be similar to that for the RPMS. However, since the major design effort would be the integration of off-the-shelf components and the writing of the software code, a breadboard model would not be required. The estimated cost and schedule is shown below.

GWCS

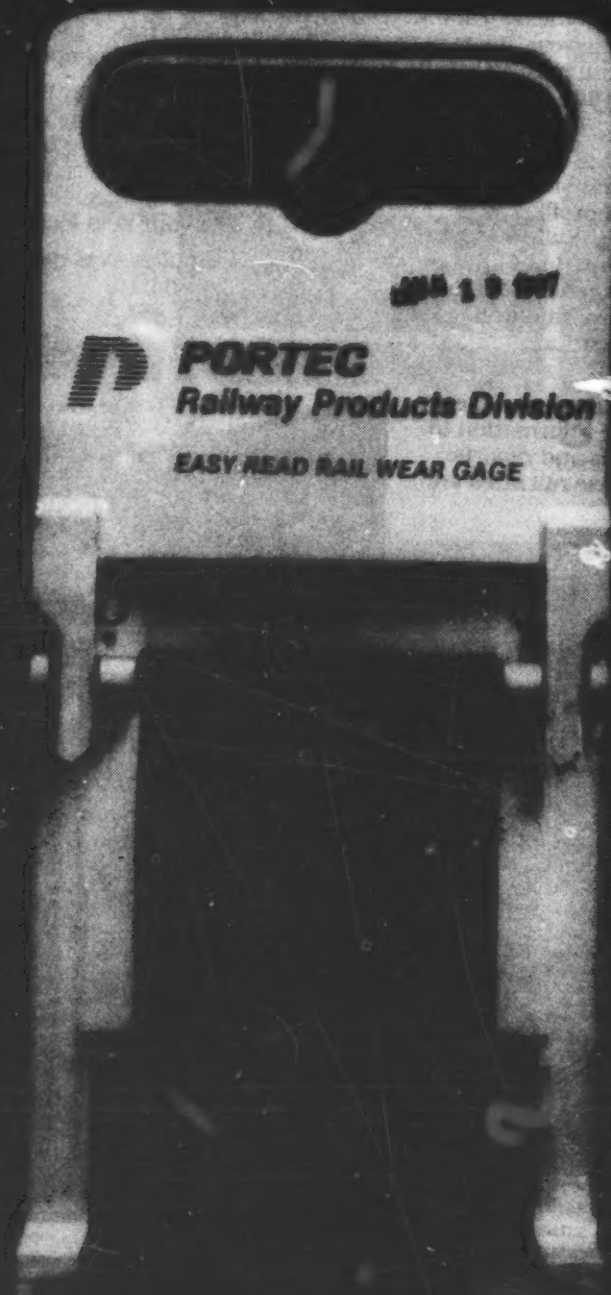
● Conceptual design	2 months
● Prototype design, build and test	4 months
● Build first production unit	1.5 months
● Field test production unit	2.5 months
● Modify and re-test production unit	1 month
● Estimated cost for materials and labour	<u>\$198,329.00</u>

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Appendix A



PORTEC

Railway Products Division

New "EASY READ" Rail Wear Gage™ Quickly and Accurately Measures Rail Wear

The new EASY READ Gage is the fastest and simplest way to measure rail wear. It's easy-to-use; you take an accurate rail profile in seconds, the very first time you try.

The EASY READ Gage uses plastic profile cards which are inserted into the cardholder. Corrosion-resistant pins transfer the rail profile onto the waterproof profile cards. By examining the position of the white impressions relative to the preprinted rail outline, you accurately determine the amount of rail wear to within 1/32 inch. Successive rail profiles can be recorded at the same location, giving you a graphic history of rail wear.

You can photocopy profile cards as an easy method for sending profile information to headquarters or for records and reports. Common 5-1/2" and 6" base rail sizes are available.

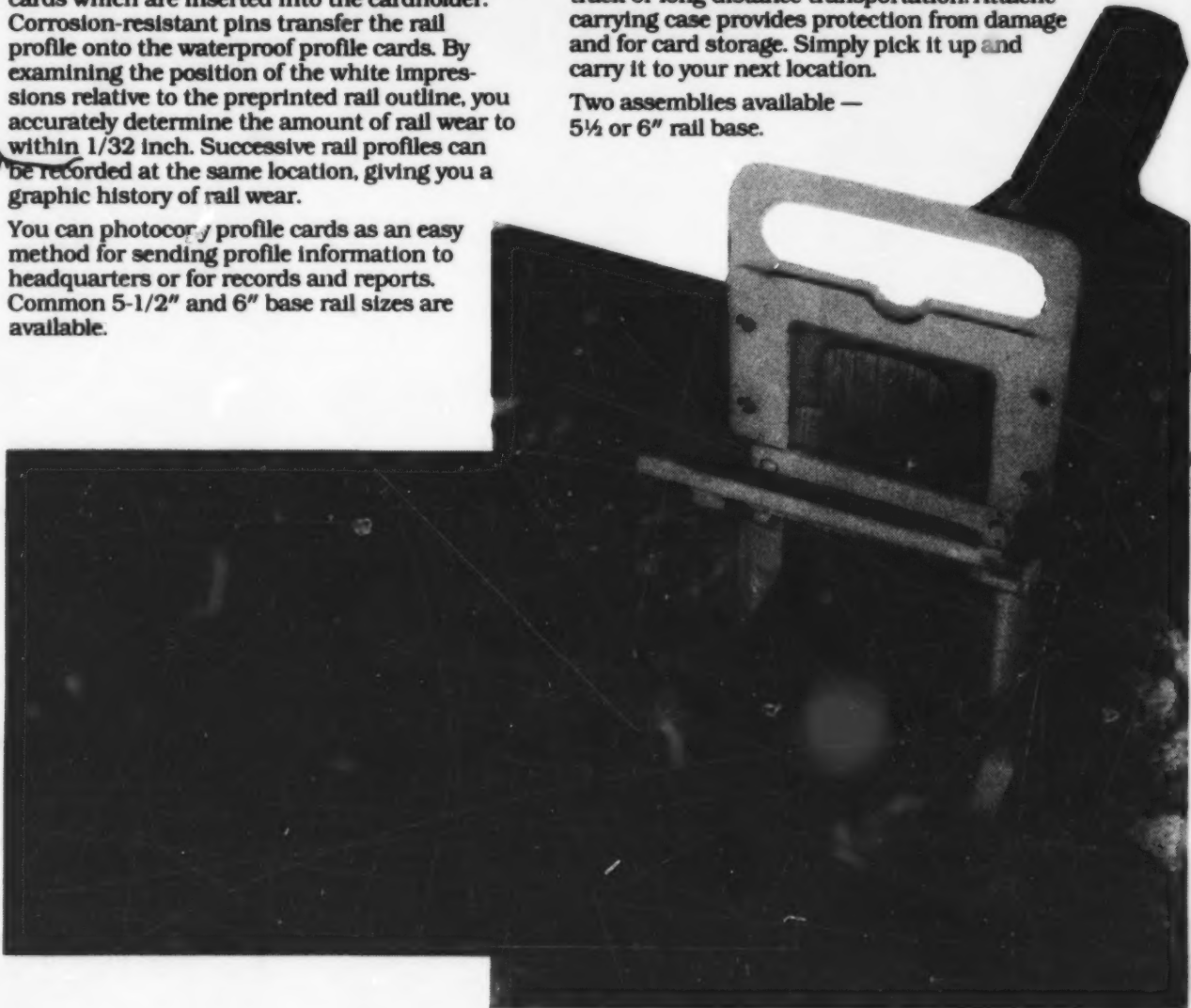
Portable, Lightweight Design

EASY READ Gage is a single, fully self-contained gage. You eliminate the need for tedious and time consuming set-up adjustments as well as periodic recalibrations.

Design of the frame makes positioning of the EASY READ Gage simple.

It is corrosion-resistant; made of lightweight aluminum. (Weighs 5 lbs.). Portable for walking track or long distance transportation. Attaché carrying case provides protection from damage and for card storage. Simply pick it up and carry it to your next location.

Two assemblies available —
5½ or 6" rail base.



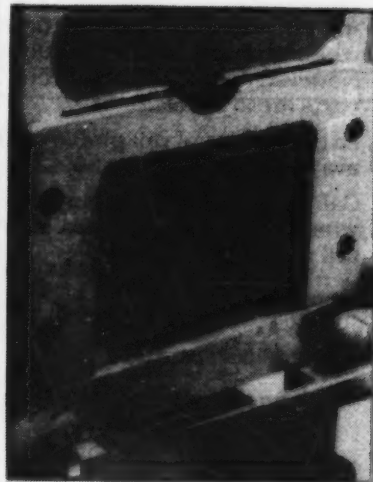
Easy to Read Easy to Operate



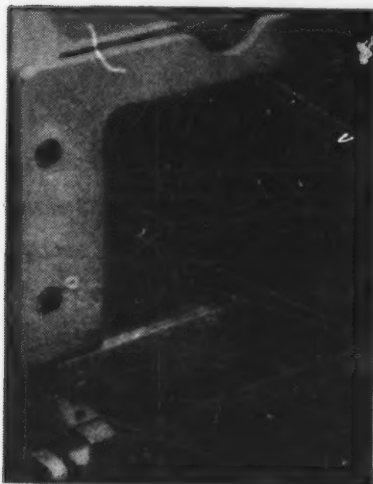
1 Select the rail profile card that matches your rail and insert into the cardholder with the blank side facing the contour pins.



2 Place gage firmly onto rail base.



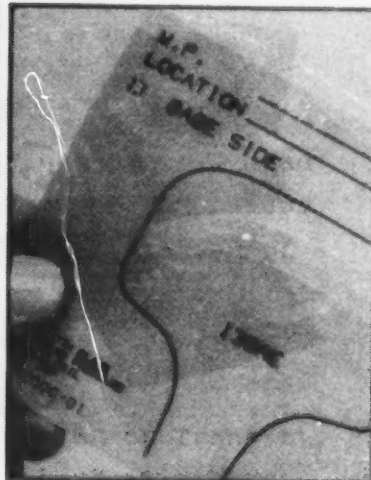
3 Grasping gage with both hands, press the brake release buttons to release pins.



4 Run your fingers along the top of the pins to make sure they have settled into position.



5 Close gage door firmly until it contacts the contour pins and squeeze. Release pressure.



6 Remove profile card and examine. Rail Wear is indicated by the distance between the imprinted profile and the pre-printed new rail profile. Before taking next reading, turn gage upside down and press brake release buttons to return pins to start position. Because the same card can be used for future measurements, fill in all information on printed side of card.



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Railway Products Division

It's That Easy!

The EASY READ Rail Wear Gage™ is the perfect replacement for cumbersome and time consuming rail wear measurement devices. It is a self-contained unit and is virtually maintenance-free. However, should damage occur, replacement parts are available.

Extra packets of rail profile cards are readily available in packages of 50.

Call us today to place your order, and see what a difference it makes. Keep track of rail wear ... with Portec.



EASY READ RAIL WEAR GAGE BY PORTEC

Portec, Inc.
300 Windsor Dr.
Oak Brook, IL 60521
(312) 920-4600

Portec, Ltd.
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1011 St. Catherine St. W.
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PORTEC

Railway Products Division

RAIL GRINDING MONITOR (RGM)

PURPOSES AND USES

The "RGM" developed by TRACK RENEWAL ENGINEERING, INC. is a dial indicator-type measuring instrument for repeatably accurate recording of changes in the rail head geometry.

The instrument base is self centering i.e. it is designed to be true to a chosen location on the rail. This particular feature is the essential precondition to both simplicity of installation and reliability of the data.

When used in PLANNING OF RAIL MAINTENANCE the RGM measures the extend of: head flow, profile changes, joint/weld batter, engine burns, gage wear, corner shelling and flaking. It also allows the prediction of the number of grinding passes necessary to reduce or remove irregularities and corrugations.

When the RGM is used as an instrument of QUALITY CONTROL it verifies conformity with specifications regarding the rail head geometry and engineering practice. Specifically, the RGM allows a timely follow-up on grinding operations and documentation of the reestablished contour or profiles.

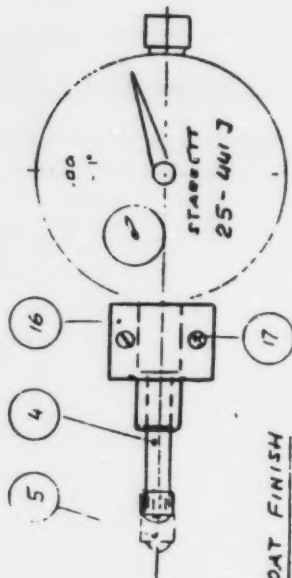
APPLICATION RANGES

All rail sections in use by the designated user (RR or Transit). Up to 27 measuring points (13 on top of the rail, 7 at either side of the ball). Up to 21 points to measure the smaller rail.

STANDARD EQUIPMENT

- 1 ea Indicator with Adaptor
- 1 ea Indicator Yoke (Instrument Base)
- 1 ea Carrying Case
- 1 ea RGM Data Collection Pad
- 1 ea Spray Paint
- 1 ea Wire and Dust Brushes
- 1 ea Hex Keys (3/32 and 3/16)

Appendix B



POS	QTY	DESCRIPTION	PART NO.
17	2	PM SOCKET SCREW	SS 7106 - 256
16	1	ADAPTOR WITH HEX KEY (3/32")	RCN - 5 60
15	8	SPRING WASHERS - SS 3/16"	RCN - 5 60
14	14	FLAT WASHERS - SS 3/16"	RCN - 5 60
13	2	SETSCREW	SS 62 12 - 255
12	3	SETSCREW MINI-D	RCN - 5 120
11	5	JAM NUT 3/8 - 18	RCN - 5 120
10	1	WIRE BRUSH (NOT SHOWN)	QJ 58 72 - 215
9	1	MURKED NUTS BATTERY SCREW	RCN - 5 90
8	1	STAINLESS STEEL NUT	MELICOL 9/16"
7	1	CARRYING CASE (NOT SHOWN)	RCN - 5 70
6	1	CLEANING BRUSH (NOT SHOWN)	RCN - 5 60
5	1	PROBE EXTENSION (1/2")	RCN - 5 30
4	1	INDICATOR - STABEFT IN 60-141	RCN - 5 60
3	1	GAGE FOOTING	RCN - 5 30
2	2	CAP NUT - SS 3/8 - 18	RCN - 5 30
1	1	INDICATOR SUPPORT	RCN - 5 30

Track Renewal Engineering, Inc.

1:1

NOV. 6-55

3/8/87

RAIL GRINDING MONITOR

RAIL GRINDING MONITOR

HOW TO USE THE RGM

1. Choose several points of measurement in every location where the rail head contour must be checked accurately.
 2. Clean the base of an 8 in. long rail section next to an anchor or tie plate (wire and dust brushes are part of RGM kit).
Spray paint may be used on the anchor to mark the measuring station.
 3. Gently position the RGM over the rail. Push it tight against the set screws on the gage side and against the anchor. Turning the knurled ratchet knob will secure the RGM in the exact same measuring location each time the rail head contour is checked.
Note: To assure the accuracy of positioning over a long period (to monitor head wear for example) use an anchor NOT butting a tie.
 4. The zero point on top of the RGM should be close to the original centerline of rail. To adjust the alignment, the lateral set screws may be repositioned. To adjust the RGM to a different size rail base, it is preferable to replace the lateral abutment with one, holding set screws in the proper alignment.
 5. The Indicator is slipped into one or more of the numbered holes on top of the RGM. The dial reading is indicating the rail height. Grinding or wear shall read as a reduction from the new section i.e. from the zero calibration.
Note: When the RGM is used to monitor head wear, the indicator's dial should be zero-adjusted on a short rail section used as calibration block and a means to check the instrument's accuracy at later times.
 6. Record the location data and the readings on the form. Make sure to write the read-out on the line corresponding to the hole where it was taken.
 7. After passage of the grinding machine repeat steps 2 thru 6.
 8. To check the rail head geometry compare the read-outs taken at equal distance from the centerline: If the rail head is symmetrical these numbers are of the same magnitude ($\pm$ a few thou).
To check the (large) crown radius, simply input three data (2, 2, and '0') into the formula on the following page.
To check the wear and general configuration of the rail head, transpose the data on the proper rail chart by simply writing (small crosses) on the acrylic sheet covers. Use the special pens stored in the form holder together with the eraser.
- NOTE: Should you need additional material or assistance in special applications, please call TRACK RENEWAL ENGINEERING, INC.
(215) 259 6610 .

SBM 200

**Rail Rectification Machine
with Swarf Collector**



Appendix C

Plasser & Theurer

Rail Rectification Machine with Swarf Collector

In modern-day rail traffic the effect of the increasing stresses on the track is a more frequent occurrence of various types of track faults, especially on the rail head.

Basically there are two types of faults:

- shallow periodic rail surface deformations such as corrugations and waves
- large rail deformations such as wheel slip marks on the inner rail of a curve, crushing on the running edge, overlaps on the outer and inner sides of rails, broken edges and material fatigue on the surface due to overstrain (particularly on shunting tracks and heavy load railways).

All these types of deformations of the rail head have considerable negative influences on the operating services, causing unsatisfactory riding quality and increased wear of the entire permanent way and the rolling stock.

Basically, surface faults up to a maximum depth of 0,4 mm are removed using the grinding technique with an economical work advance.

The elimination of large rail deformations, however, which requires the removal of a substantial amount of material, can only be treated by using the rail planing technique. Planing defective rails has been a recognised method of treatment for some years, which until now could only be used in reconditioning plants using stationary machine tools. Despite its efficiency this method is labour and cost-intensive because the rails have to be removed from the track and transported to the plant for treatment, then returned and re-inserted into other lines.

For some years now Plasser & Theurer has concentrated on the

problem of a technically perfect and economically feasible method of removing these rail deformations in track, based on the rail planing technique.

The result of the research was the introduction in 1979 of the first mobile on-track rail planing machine SBM 100.

Two machines of this type, one on the Austrian Federal Rail-

ways and the other on British Rail, underwent extensive tests and both produced excellent operating results.

From the experiences with the SBM 100 came the series machine SBM 200, an economical, efficient and versatile machine which is capable of removing rail defects with large deformations in situ using the rail planing technique.



Design

The SBM 200 is built in standard railway vehicle design. In compliance with this the main frame has the regulation strength of 2000 kN longitudinal thrust and 400 kN diagonal buffer thrust, and is equipped with a buffer bar at both ends so that the machine can be hauled in train formation when fitted with buffer and draw gear. The frame was tested mathematically according to the method of finite elements. The sturdy frame construction is manufactured from profile bars, rolled girders and steel sheets using the most up-to-date welding techniques and production methods.

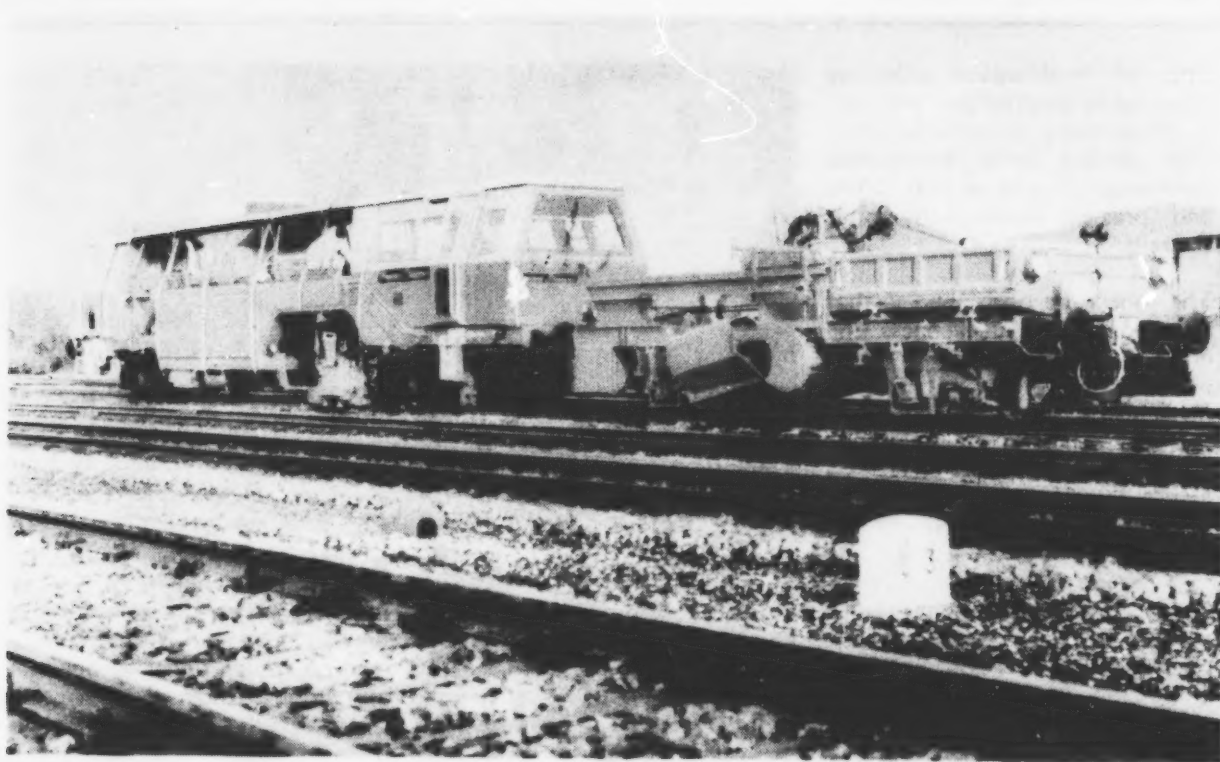
The chassis comprises two 2-axle bogies with rigid axles. Plasser & Theurer bogies are specially designed for the track maintenance machines and are well-proven worldwide on the Plasser &

Theurer 07 and 08 series tamping machines.

Rubber-metal packs between the axle bearing housings and the bogie frame, and between the bogies and the machine frame, as well as a shock absorber between the axle bearing housings and the bogie frame provide sufficient absorption of vibrations and ensure smooth vehicle running.

The machine is equipped with directly operated compressed-air block brakes in compliance with UIC regulations which act with one brake block on each wheel. A mechanically operated parking brake acts on all wheels of the rear bogie. The machine is equipped with a continuous brake pipe. Furthermore, it is possible to install both an indirect train braking system with KE valve

SBM 200



which enables the machine to be braked from the locomotive when riding in train formation as well as a driver's brake valve which in connection with the indirect train brake system enables hauled waggons to be braked from the machine. When the maximum permissible wear of the brake blocks is reached, this is indicated by warning lamps.

The power pack is located in the centre part of the vehicle. For transfer travel power is supplied hydrodynamically from the engine via torque converter, power shift transmission, distributor gearbox and drive shafts to the axle gearboxes of the axles of the front bogie. During work all four axles are hydrau-

lically powered, thus producing the high traction forces required for simultaneous planing of both rails. By synchronising the two power supplies an even distribution of the traction forces on all axles is guaranteed. The engine compartment doors are lifted and lowered via hand crank and chain hoist. This makes the engine easily accessible from all sides.

At the front and rear end of the machine there are spacious enclosed cabins, mounted on resilient frames and sound-proofed to ensure greatest possible absorption of vibrations. The rear cabin contains all operating and monitoring controls for work and transfer travel, clearly laid out. Another driver's console is located in the front cabin for transfer travel (optional extra). Large

safety-glass windows ensure a good view onto the entire work area and along the track. The cabins are equipped with an intercom system. A sliding door is located on the front wall of the rear cabin to enable access in-between the grinding units. This avoids danger to the machine operator when changing the grinding tools and when servicing the planing units. The machine is fully roofed-over from the front to the rear cabin. Moreover, it is possible to equip the machine with compact sound insulation, which lowers the noise level considerably. The engine compartment is fully lined with sound-proofing material and fitted with the necessary noise dampeners at the intake and exhaust openings. Cooling and combustion air is taken in through a channel with an opening in the roof.

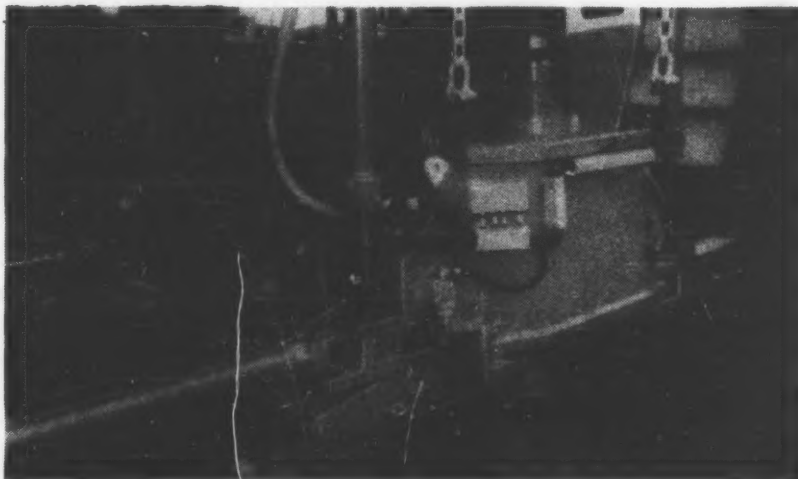
Rail Rectification Machine with Swarf Collector

Grinding Units

The rail rectification units are operated hydraulically.

The planing units are guided by horizontal and vertical rollers and pressed hydraulically onto the rails.

The rollers are positioned so that in the case of unevenness the grinding units follow the tips of the corrugations and thus always make a straight longitudinal movement. Each grinding unit has a tool carrier for holding the planing knife which is inserted using quick release fittings. The side or depth adjustment of the planing knives is done hydraulically, permitting continuous adaption to the work conditions. The adjustment values are fed in at a special display instrument via digital potentiometers and primary elements.



The adjustment of the planing knives according to the pre-selected cutting depth is first done when a pre-selected speed is reached. Below this cutting speed the planing knives return automatically to their original posi-

tion. In the planing frame the high pressure jets are positioned in such a way that the cutting surfaces can be cooled under all operating conditions, thus giving optimal usage of the service life of the planing knives.

Swarf Collector



The continuous action Swarf Collector SPS was developed by Plasser & Theurer for the immediate removal from the track of the metal cuttings produced during rail planing. The immediate collection of planing swarf avoids

danger to persons and material.

The SPS is designed as a 2-axle trailer to the SBM 200. The power supply comes from the planing machine. The swarf is picked up by magnetic drums, passed on to

conveyor belts and carried to a storage bin. An overhead crane with lifting magnet transports the swarf in automatic work cycle to the loading platform of the SPS. The magnetic crane is also used to off-load the swarf.

Measuring equipment

The SBM 200 can be equipped with measuring equipment which can register both the condition of the rails before planing and record the final work results.

With the aid of three sensors

positioned across the rail, the convexity and lateral tilt of the running surface is measured continuously. The system is designed so that the frequency curve is linear up to a wavelength of 2 m and thus the actual course of the

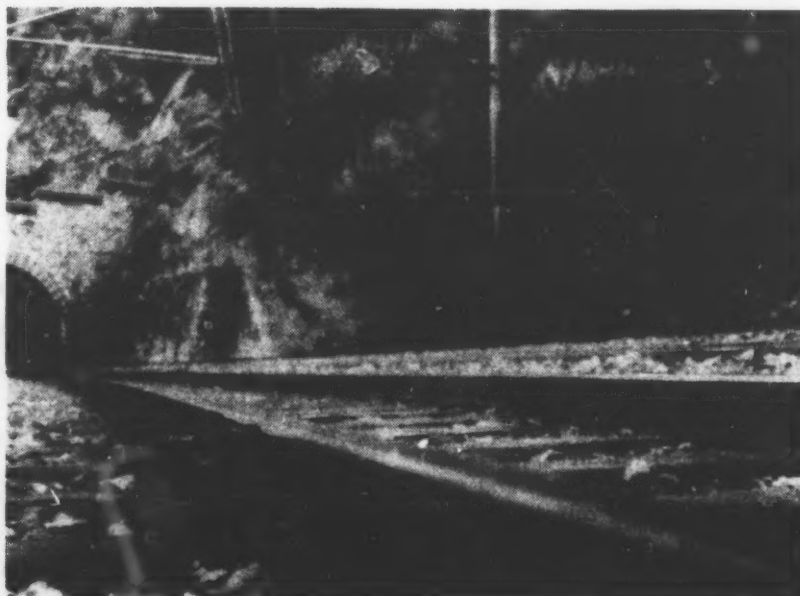
surface corrugations is measured. By the addition of appropriate electronic filters, information can also be obtained on the occurrence of short and long wave faults.

Application

The Rail Rectification Machine SBM 200 has a high cutting capacity and is put to use wherever it is necessary to remove large amounts of material that is to say, where the rail profile has to be altered or re-profiled.

The main areas of application are as follows:

- deep wheel slip marks (e.g. on the inner curve rail)
- overlaps and crushing of the rail edges (e.g. on drag shoe tracks and station tracks, mountain lines and heavy load railways)
- wheel burns
- cracking and breakage along the running edges
- undercutting of hardening cracks on the running surface caused by cold forming
- preventive rail treatment (e.g. removal of fatigue-endangered zones on the rail surface which avoids greater damage to the rail)
- undercutting of corrugations and waves
- re-profiling of an existing rail profile for technical reasons
- alteration of an existing rail profile for better rail/wheel relationship.



Rail Rectification Machine with Swarf Collector

Work technology

The SBM 200 can treat both rails simultaneously. Work can also be done in either direction, thus offering a high potential output. Both long welded rails and jointed track can be treated. In principle, any surface of the rail head can be planed.

In general the following types of treatment are usual:

- rail surface
- inner and outer rail edge

For the removal of faults on the rail edges three passes are normally sufficient. First a cut under 45 degrees, followed by a faceted cut with two blades under 22,5 and 67,5 degrees. For the final cut a contouring knife is used to produce the rounded edge in the corresponding radius. When treating the rail surface four cuts normally suffice to produce a perfect longitudinal and cross-section profile, achieved by facet cuts.

On British Rail a technique has been developed whereby the running edge and the rail surface are re-profiled. The rail planing machines in regular service on British Rail are using this work method with good results. During the entire planing sequence the centre of the rail head is the reference line. That is the reason why the cut which removes this reference line is carried out last. If the entire rail head is to be reprofiled the three edge cuts will be repeated as required on the opposite rail edge.

However, in most cases, depending upon type and location of rail faults, total re-profiling is not necessary. Often it is sufficient to recondition the running edge and slice off the outer edge. For drag shoe tracks and railway tracks a rough treatment of the edges is sufficient.

On plain line tracks with deep wheel slip marks the rail surface requires more intensive treatment. On curved lines it is usually sufficient to treat the inside rail.

By this adaption of the minimum number of cuts to the prevailing type of wear, the grading machine achieves an optimal degree of utilization and efficiency.

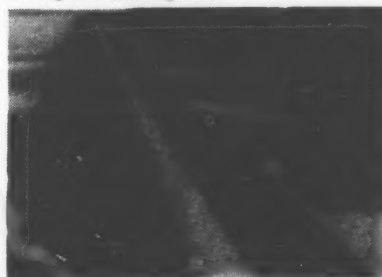
Example of Reprofiling the Running Edge and the Surface



1. Edge cut (45 degrees)



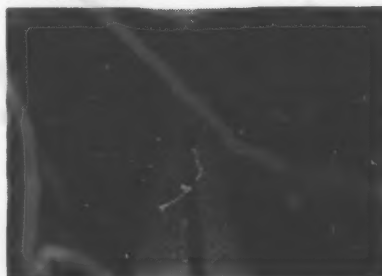
2. Edge cut (22,5 and 67,5 degrees)



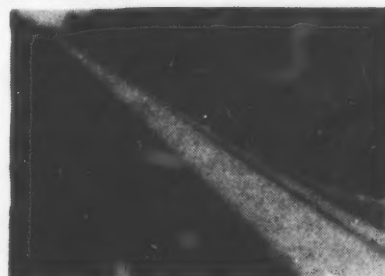
1. Surface cut



2. Surface cut



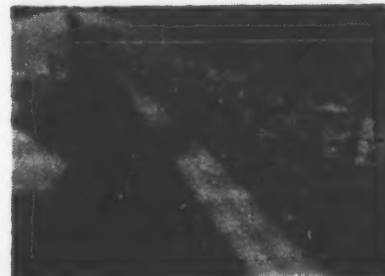
3. Surface cut



contour cut



4. Surface cut



reprofiled rail

Economy

A cost study for the application of a mobile rail planing machine as well as for stationary rail treatment based on central european railway administrations produced an advantage in favour of the mobile grinding machine over and above an annual planing length of

only around 15 km.

A cost analysis on British Rail showed that the capital costs of the machine were covered twice over after a period of 6 months in which 32 km of track of good quality were reprofiled and thus did not have to be re-

placed by new rails.

Since the SBM 200 can easily attain annual outputs of 100 km planing length, considerable savings can be made compared to conventional methods of rail rectification.

Summary

With the Rail Rectification Machine SBM 200 Plasser & Theurer has produced a machine which enables in-situ rail planing. This effective technique of rail rectification has thus become universally applicable and economically feasible. The machine design makes it possible for the SBM to adapt well to the most varied requirements of the railway administrations and the necessities of the operating conditions.

One example is the combined rail rectification and grinding machine SBM 111 which is in operation on the Berlin Transport Authority. The SBM 111 makes it possible both to carry out complete reprofiling of the rail head and the necessary grinding work with one machine. Per work pass the rail is either planed or ground.

Power is supplied either Diesel-hydraulically or electro-hydraulically.

Other mobile rail rectification machines, in modified design to suit the requirements, are working on the Austrian Federal Railways, British Rail, in Brazil and in Australia with good success.

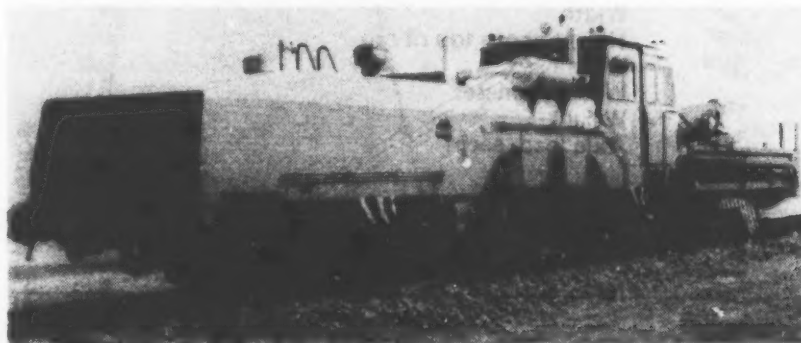
With the development of the mobile rail rectification machine SBM 200 with swarf collector



Combined Rail Rectification and Grinding Machine SBM 111



Rail Rectification Machine with grinding trailer SBM 200 for Brazil



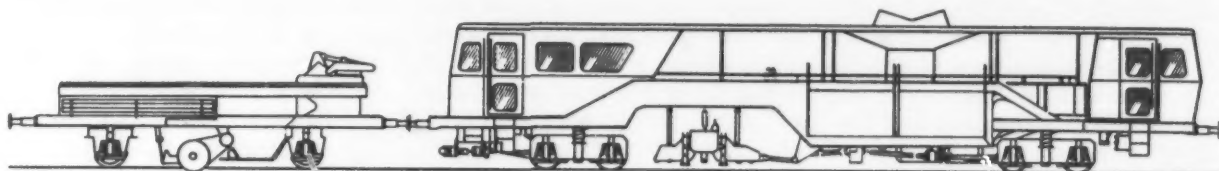
Rail Rectification Machine SBM 140 operating in Australia

Plasser & Theurer has created a system of on-track rail rectification which meets all demands

of mechanised treatment of rail head faults in a safe, economical and high quality manner.

Rail Rectification Machine with Swarf Collector

SBM 200



Technical data: Planing Machine



Length over buffers	18 900 mm
Width	2 500 mm
Height above top of rail	3 680 mm
Bogie pivot spacing	11 000 mm
Bogie wheelbase	1 500 mm
Wheel diameter	710 mm
Weight	60 t
Front axle loads, each	15 t
Rear axle loads, each	15 t
Engine output	188 kW (256 HP)
Maximum speed under own power	80 km/h
Maximum speed in train formation	100 km/h
Work speed	20 - 80 m/min

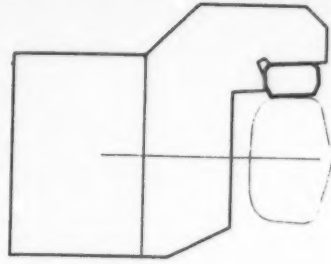
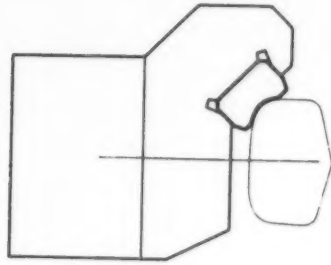
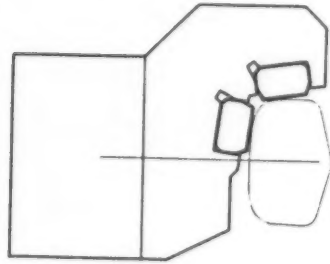
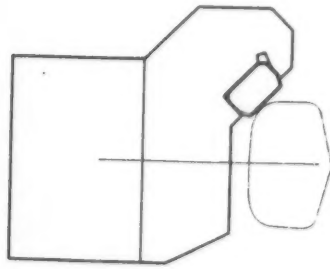
Swarf Collector

Length over buffers	9 040 mm
Width	2 500 mm
Height above top of rail	2 650 mm
Wheelbase	4 500 mm
Wheel diameter	710 mm
Weight	16 t
Axle load, each	8 t

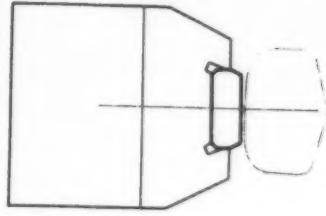
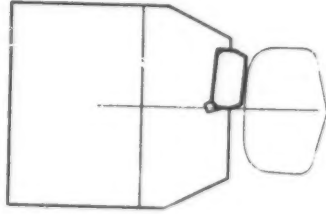
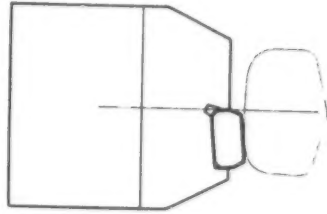
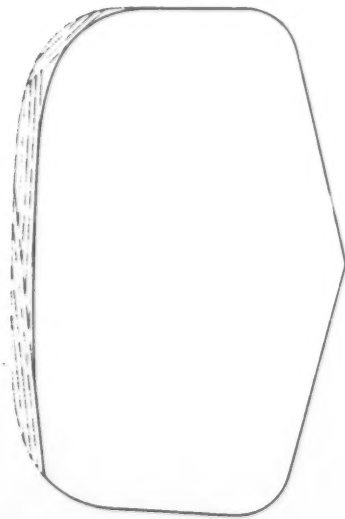
The machines illustrated may include optional equipment.
We reserve the right to make alterations in line with
the further technical development.



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Sample cut sequence



Radius cuts with various
planing heads